GEOLOGY AND GROUND-WATER RESOURCES

By Dee Molenaar

WELL AND LOCATION-NUMBERING SYSTEM

In this report wells and locations are designated by symbols that indicate their locations according to the official rectangular public-land survey. For example, in the symbol 24/1E-33K1, representing one of the City of Bremerton's wells, the part preceding the hyphen indicates successively the township and range (T. 24 N., R. 1 E.) north and east of the Willamette Meridian and Baseline. Because the report area lies entirely north of the Willamette Baseline the letter indicating the direction north is omitted, but the letters "E" or "W" are included to describe the range's position east or west of the Willamette Meridian. The first number following the hyphen indicates the section (Sec. 33), and the letter "K" gives the 40-acre subdivision of the section, as shown in Figure 9.

The last number is the serial number of the well in the particular 40-acre tract, if more than one well is listed. Thus, well 24/1E-33K1 is in the NW¼SE¼, Sec. 33, T. 24 N., R. 1 E. and is the first well in the tract to be listed.

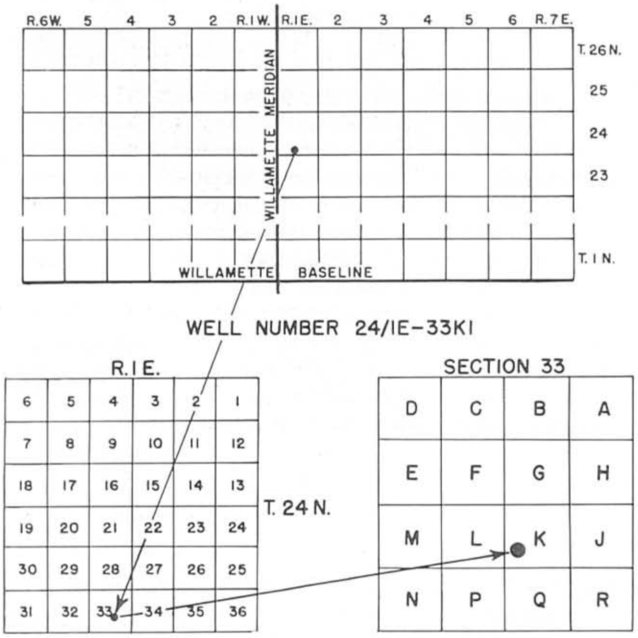


Figure 9. DIAGRAM SHOWING WELL AND LOCATION-NUMBERING SYSTEM

GEOLOGY OF THE REGION

GEOLOGIC HISTORY

A knowledge of the sequence of geologic events that formed the various rock units within the report area will give an understanding of the extent and occurrence of these formations, which in turn will aid in understanding the occurrence of ground water within the area. As the oldest rocks found on the Kitsap Peninsula are of Tertiary Age, the following discussion will cover only the sequence of geologic events of the Tertiary Period through the Quaternary Period.

TERTIARY PERIOD

During the early and middle Eocene Epoch of the Tertiary Period great thicknesses of basaltic and andesitic lavas were extruded from fissures or cones and were laid down across a broad, northwest-southeast trending piedmont plain that occupied most of what is now western and southwestern Washington. A fluctuating sea level and shoreline at that time caused portions of the plain to lie alternately above and below sea level, resulting in deposition of some of the lavas in marine waters. Stream sediments derived from the volcanic rocks were also deposited throughout the area, some forming interbeds and lenses between lava rock units. By late Eocene time the volcanic activity had decreased considerably and a period of quiescence followed, during which time, and extending through the Oligocene and early Miocene Epochs, thousands of feet of marine sedimentary rocks accumulated on top of the volcanic rocks.

During late Miocene time the volcanic and sedimentary formations were deformed into large northwest-southeast trending folds, producing the ancestral Cascade Mountains. Erosion during early to middle Pliocene time reduced these mountains considerably. At the close of Tertiary time, during the late Pliocene Epoch, a north-south uplift produced the present Cascade and Olympic Mountains, with an accompanying downwarp between forming the present Puget Trough (Fenneman, 1931, p.450).

QUATERNARY PERIOD

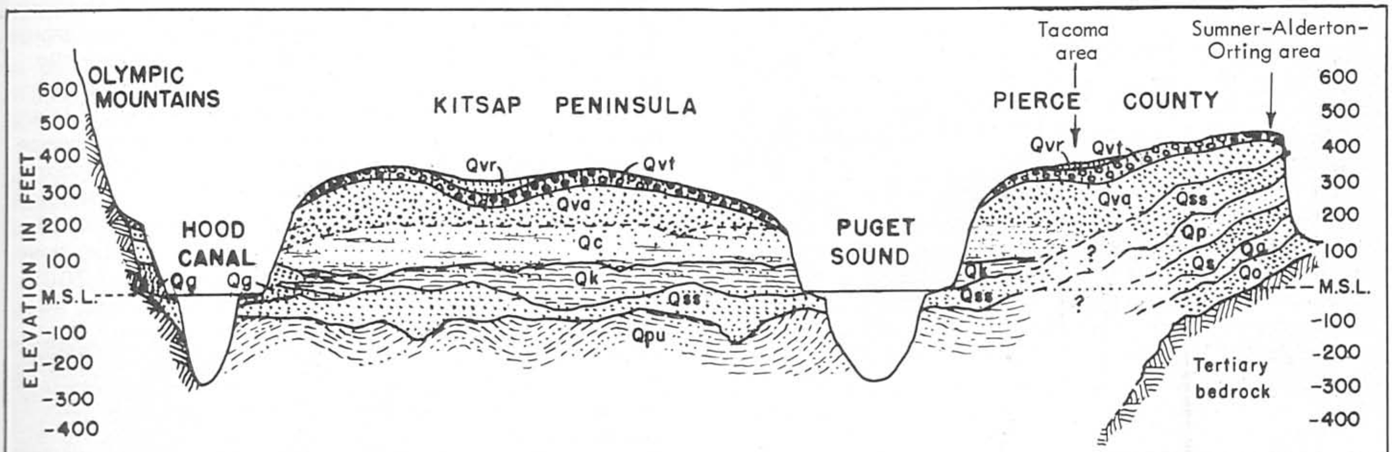
Pleistocene Epoch

During late Pliocene and through most of Pleistocene time what is now the Puget Sound lowland was the site of deposition of sedimentary materials. These sediments consist principally of varying thicknesses of fine-grained silts and clays, alternating with coarser sands and gravels. The finer sediments are believed to have accumulated in fresh-water lakes and swamps. Thin strata of volcanic ash found in the finer-grained materials indicate that some volcanic activity was occurring in nearby areas during this time. Woody materials accumulated locally in shallow lakes or swamps, resulting in the lenses and beds of peat and lignite found today. The coarser materials were laid down both as stream deposits from bordering mountain valleys and as glacial drift materials laid down by several large ice sheets which occupied the Puget Sound lowland during the Pleistocene Epoch.

During the Pleistocene "Ice Age" vast glaciers originating in Canada pushed several times into the Puget Sound lowland. Ice sheets 2000 to 5000 feet thick covered the area as far south as the vicinity of Tenino in southern Thurston County. A fluctuating climate caused the ice mass to alternately grow and advance, and melt and "retreat," several times during Pleistocene time, with the last ice disappearing from the report area approximately 14,000 years ago.

From the front of each glacier issued large streams which deposited sands and gravels, and in many places cut new channels and valleys for later filling by such sediments. Fine silts and clays were deposited in lakes formed locally in ice-dammed drainages. Warming of the climate for long periods caused large scale retreats of the ice from the area and permitted the growth of vegetation and even forest cover similar to that of the present day. As the climate again cooled and ice again invaded the lowland areas, these forest and swamp materials were buried under the stream and glacial deposits and are today found as compacted peat beds lying within clay and silt materials. A primary deposit associated with each glacier advance is till or "hardpan," normally a gray to bluish-gray, compact mixture of cobbles in a binder of silt and clay. This material was "smeared" along as a basal deposit of each ice sheet and mantled the pre-existing topography over which the ice advanced.

Each period of glacial advance into the Puget Sound lowland was followed by glacial retreat and subsequent erosion of some of the glacial drift materials. Because much of the depositional record was thus destroyed, it is difficult to determine the number of times that major ice sheets entered the lowland, particularly during the early and middle Pleistocene Epoch. However, since publication of the report on the geology of Kitsap County (Sceva, 1957), several additional field investigations have been made of the complex stratigraphy of Quaternary sediments found in various parts of the Puget Sound lowland. These studies have resulted in considerable modification of earlier concepts held on the number and sequences of glacial and nonglacial stages within the Pleistocene Epoch. According to Crandell and others (1958) who studied the Pleistocene stratigraphy of the Sumner-Alderton-Orting area in Pierce County, the earlier concept of two major glaciations must now be replaced by one that allows for at



KITSAP PENINSULA	DEPOSITIONAL INTERVAL	PIERCE COUNTY MAINLAND (Crandell & Others, 1958; Walters & Kimmel, in preparation)
Vashon Drift: Qvr-recessional outwash, Qvt-till, Qva-advance outwash, Qc-Colvos Sand	Fraser glaciation	Vashon Drift: Qvr-recessional outwash, Qvt-till, Qva-advance outwash
Qg/Qk: Qg -unnamed gravel, Qk-Kitsap Formation	Olympia interglaciation	Qk-Kitsap Formation
Qss-Salmon Springs(?) Drift	Salmon Springs glaciation	Qss-Salmon Springs Drift
Qpu-pre-Salmon Springs(?) deposits, undifferentiated	Puyallup interglaciation	Qp-Puyallup Formation
	Stuck glaciation	Qs-Stuck Drift
	Alderton interglaciation	Qa-Alderton Formation
	Orting glaciation	Qo-Orting Drift

Figure 10. DIAGRAMMATIC WEST-EAST CROSS SECTION OF THE SOUTHERN PUGET SOUND LOWLAND, SHOWING A TENTATIVE CORRELATION BETWEEN THE PLEISTOCENE STRATIGRAPHIC UNITS OF THE KITSAP PENINSULA AND THE PIERCE COUNTY MAINLAND. The Sumner-Alderton-Orting area was studied by Crandell and others (1958), and the Tacoma area was studied by Walters and Kimmel (in preparation).

least four glaciations. These studies, and a later summary of the late Pleistocene stratigraphy and chronology of the Strait of Georgia and Puget lowland by Armstrong and others (1965), now name the following sequence of glacial and nonglacial intervals:

Fraser glaciation (youngest)
  Olympia interglaciation
Salmon Springs glaciation
  Puyallup interglaciation
Stuck glaciation
  Alderton interglaciation
Orting glaciation

In the Kitsap Peninsula area, only two readily recognizable major glacial drifts have been found by the author. The younger of these was named the Vashon Drift by Willis (1898, p. 126) and this designation has been accepted by all subsequent writers. The older of the two drifts has here been tentatively correlated to the Salmon Springs Drift (Crandell and others, 1958) but, owing to lack of direct correlation to date with the type localities near Sumner, Alderton and Orting, it was deemed advisable to identify the Drift found in the Kitsap Peninsula area with query. Figure 10 shows the writer's tentative correlation between the depositional intervals as interpreted from stratigraphic units found in the report area with those compositely described on the Pierce County mainland by Crandell and others (1958) and Walters and Kimmel (in preparation).

Warming of the climate at the close of the Salmon Springs glaciation resulted in melting and northward retreat of the ice from the lowland. The lowland sediments then became subject to erosion, reworking, and partial bevelling by streams from the adjoining Cascade and Olympic Mountains. The streams carried sediments from the mountains and deposited them across the partially eroded lowland. An aggradational floodplain was developed during this nonglacial period over most of the area now occupied by Puget Sound and the Strait of Georgia. Slow, meandering streams, shallow lakes and marshes formed the predominating environment for the deposition of fine silts, clays and peats. These materials, named the Kitsap Formation, were deposited in the report area during the Olympia interglaciation.

Following deposition of the nonglacial Kitsap Formation a cooling climate again brought on the growth of continental glaciers in the north, and a thick sequence of massive- to well-bedded proglacially deposited sand with lenses and interbeds of gravel and clay was laid down across the surface of the Kitsap Formation. In places lakes were formed and partially filled by well-bedded clays. Evidence to date fails to clearly define the depositional environment of these materials, named the Colvos Sand (see p. 33). Because the sands exhibit no general decrease in grain size southward throughout the report area, it appears that the depositional environment in which the Colvos Sand was laid down remained relatively constant, and shifted southward with the movement of a major ice sheet. Until more detailed studies are made of the Colvos Sand, the writer proposes that the sediments were laid down as a proglacial deposit at some distance beyond the advancing front of the Vashon glacier.

The Vashon glacier entered the northern Puget lowland following deposition of the Colvos Sand and overlying coarser proglacial gravels. According to radiocarbon dating of wood and peat from nonglacial deposits beneath these Vashon Drift materials, the glacier entered the north end of the Strait of Georgia in British Columbia since 25,000 years ago (Armstrong and others, 1965). The approximate date of the glacier's entry into the Kitsap Peninsula area is not established at this writing, owing to a considerable variation of radiocarbon dates obtained from sediments found directly beneath Vashon Drift throughout the Puget lowland.

The rate of southward movement of the Vashon glacier across the report area has been suggested by radiocarbon dates obtained for preglacial and postglacial peat beds found in the Seattle area by Mullineaux and others (1965). Dates from wood fragments found in nonglacial sediments lying beneath the Lawton Clay Member of the Vashon Drift indicate that nonglacial conditions prevailed at the latitude of Seattle until at least 15,000 years ago. Dates of samples taken from sediments directly overlying Vashon Drift show that the glacier had retreated from this latitude in the Kitsap Peninsula area prior to 13,500 years ago. Between these limiting dates it is shown that the ice occupied the Seattle area for no longer than 1,500 years. As this period must also allow for the deposition of advance and recessional outwash sediments the actual interval of occupancy by the Vashon glacier may have been considerably shorter.

As the glacier advanced in the Puget Sound lowland, separate ice tongues pushed into valleys existing in the pre-Vashon topography and cut these deeper while adjacent interlobe "highs" received sand and gravel deposits from streams which aggraded laterally and ahead of the separate ice tongues. As the ice thickened, the tongues coalesced and eventually covered most of the lowland. The ice continued to cut and deepen the valleys, with ice erosion penetrating deeply into the underlying materials, including the glacier's own advance outwash deposits of gravel and coarse sand, the Colvos Sand, The Kitsap Formation, and the older materials. The valleys thus cut extended 300 to 900 feet below present sea level. This depth of cutting by the ice is not extreme when one considers that the Vashon glacier attained thicknesses of 2000 to more than 4000 feet over the Kitsap Peninsula area, as indicated by the presence of glacial erratics deposited by the ice at these elevations on the adjacent flanks of the Olympic Mountains. At the maximum extent of the Vashon glaciation, the ice moved into what is now the southern part of Thurston County and butted against the foothills of the Black Hills. The materials removed by the glacial erosion of the valleys were carried southward by outwash streams and were either deposited across the southern part of the lowland or were carried into the Chehalis River drainage via the Matlock and Gate Pathways described by Bretz (1913).

Near the close of the Pleistocene Epoch the front of the Vashon glacier began to recede from the Puget Sound lowland. The uplands and hills were the first areas freed of ice. Meltwater streams flowed across the exposed areas, eroding some of the earlier deposits and redepositing these sand and gravel materials in broad channels. Deltas formed at many places where streams terminated in lakes and ponds that were impounded by ice tongues still occupying the valley areas. A series of lakes thus formed in the valleys gradually abandoned by the retreating ice front became the sites for deposition of the fine-grained thinly stratified, well-bedded clays of glacial Lake Russell (Bretz, 1910). As the ice continued to melt, the meltwater streams and levels of the impounded lakes shifted to progressively lower altitudes. Finally, upon complete disappearance of ice from the Puget Sound lowland, marine waters entered by way of the Strait of Juan De Fuca and replaced the glacial lake waters, forming the present day salt-water embayments and channels of Puget Sound.

Recent Epoch

In Recent time deltas have formed at the mouths of the larger streams that discharged into Puget Sound. Where filled with stream sediments to above sea level, they today form the broad river bottomlands which head many of the marine embayments. Peat and silt deposits have accumulated in ponds that developed on the irregular glacial topography, and a relatively thin soil mantle has developed throughout most of the area. Postglacial streams have eroded deep canyons in the uplands, while slumping and wave erosion have steepened many of the slopes extending from the uplands to the waterways of Puget Sound. The processes of erosion of uplands, and deposition of river silts and sands into the lowlands and headwaters of the Puget Sound inlets continue through the present day.

DESCRIPTION OF ROCK UNITS

TERTIARY ROCKS

Volcanic Rocks

The oldest rocks found in the Kitsap Peninsula are the thick sequence of basaltic flows that underlie the Green Mountain-Gold Mountain hills west of Bremerton. These volcanic rocks have been correlated to rocks found on Vancouver Island, British Columbia, which were first described and named the Metchosin volcanics by Clapp (1909). Although first assigned a late Mesozoic Age, they have since been described on the Kitsap and Olympic Peninsulas of Washington as being of Eocene Age (Weaver, 1937).

In the Green Mountain-Gold Mountain hills the flows consist principally of dark, fine-grained basalt. Some flows have an amygdaloidal texture where vesicular bubble holes have become filled with secondary minerals. In the quarry at 24/1E-28 on Sinclair Inlet, several flows are discernible, with a maximum thickness of individual flows being about 30 feet.

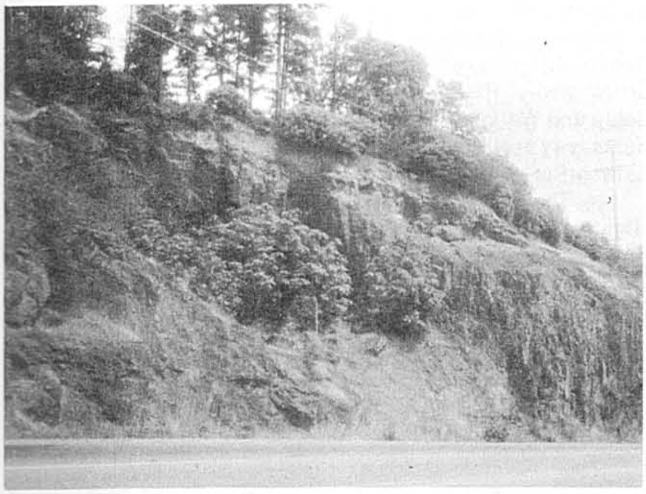


Figure 11. TERTIARY BASALT FLOWS. Exposed in road cut along Sinclair Inlet at 24/1E-28.

Associated with the flows are crystalline igneous rocks which as dikes and sills have locally intruded the finer-grained basalts. These rocks are usually coarse-grained diorite and basalt porphyry and are exposed in the quarries at 24/1W-3P and 24/1W-8A on the north slopes of Green Mountain.

The total thickness of these volcanic rocks is not known. In an oil test well at 22/1W-11J the drill encountered these rocks at a depth of 700 feet and had not passed through them at a depth of 6,688 feet (Sceva, 1957, p. 13).

Sedimentary Rocks

A thick sequence of well-indurated marine sedimentary rocks crops out in the sea cliffs near the southern end of Bainbridge Island, and in the opposite shore of Rich Passage from Waterman to Orchard Point. Similar rocks are also exposed in the entrance to Dyes Inlet at the western end of the Port Washington Narrows. They consist of conglomerate, sandstone, and shale composed mainly of erosional products from a volcanic terrain. These rocks were described and named the Blakeley formation by Weaver (1912, p. 10-22), who later determined their age as Oligocene. The total thickness of this formation in the report area is estimated to be more than 8,500 feet (Weaver, 1937, p. 151), although its base and upper surface are not exposed. The formation was folded and later bevelled by erosion in late Tertiary time and strata that were once practically horizontal are now inclined at angles of 45-degrees to nearly 90-degrees (Fig. 12). A marked angular unconformity exists between this formation and the overlying Pleistocene sedimentary materials.

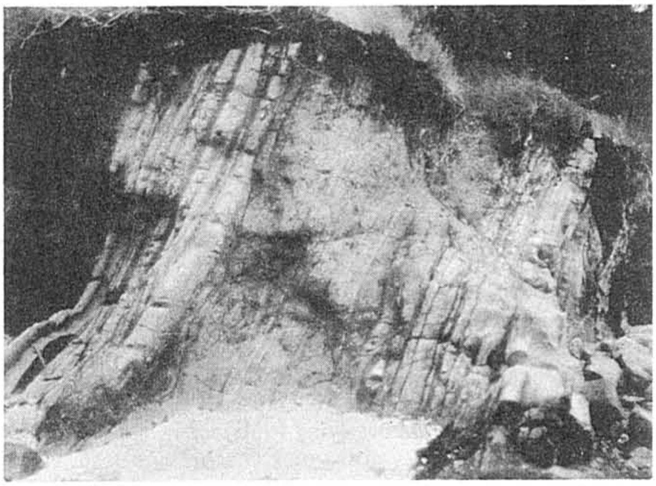


Figure 12. BLAKELEY FORMATION. Nearly vertical strata exposed above beach at 24/2E-8J northeast of Port Orchard.

QUATERNARY DEPOSITS

Pre-Salmon Springs(?) Deposits, Undifferentiated

A great thickness of unconsolidated sedimentary materials overlies the Tertiary rocks in the Kitsap Peninsula and represents an accumulation of glacial and nonglacial sands, gravels, clays and till during early to middle Pleistocene time, prior to the Salmon Springs glaciation.

As observed in a number of exposures at the base of beach bluffs, and as described in drillers' logs, these sediments are composed primarily of fine-grained sands, silts, and clays which were named the Admiralty drift by Willis (1898). Owing to the recognition of a till unit within these materials the sediments were considered by Willis to be representative of a single glaciation prior to the Vashon glaciation. Bretz (1913, p. 175-177) recognized two distinct tills within the Admiralty drift but still accepted the name given the formation by Willis. As discussed earlier, subsequent studies by Crandell and others (1958) have shown evidence of at least three major glaciations prior to Vashon glaciation. The term Admiralty drift, used by Sceva (1957) to describe these older materials, has been replaced in this report by the term pre-

Salmon Springs(?) deposits, undifferentiated. This unit includes both glacial and nonglacial materials.

The upper surface of these sediments is marked by an erosional unconformity which is below sea level in most places in the Kitsap Peninsula but is exposed in a few places at the base of sea cliffs. Owing to the heavy cover of vegetation obscuring the upper surface, the top of the pre-Salmon Springs(?) deposits, undifferentiated is not readily observed in most places. However, well log data indicates the surface to be deeply eroded. Elevation differences of 300 to 400 feet are common between ancient hills and valleys.

These older sediments are exposed along the base of beach bluffs at Point Southworth and south along the west shore of Colvos Passage to a point below Fragaria. On Vashon Island, on the east shore of Colvos Passage, they are found forming a steep resistant bluff at 23/2E-26G near Cove (Fig. 13a) and also south of Lizabeula at 22/2E-14D, where they may be seen attaining a vertically tilted position probably as a result of ice shove by the Vashon glacier. The older sediments are also exposed in a small outcrop at 22/3E-19C on the north shore of Quartermaster Harbor (Fig. 13b). On the Longbranch peninsula they form the major part of the South Head peninsula 20/1E-6.

The above-described exposures consist chiefly of massive, frequently contorted strata of hard clay and silt, with horizontal, well-defined bedding rare. Where a hard, horizontally bedded clay has been found, it has been mapped with the Kitsap Formation, although it may in fact be associated with the older materials.

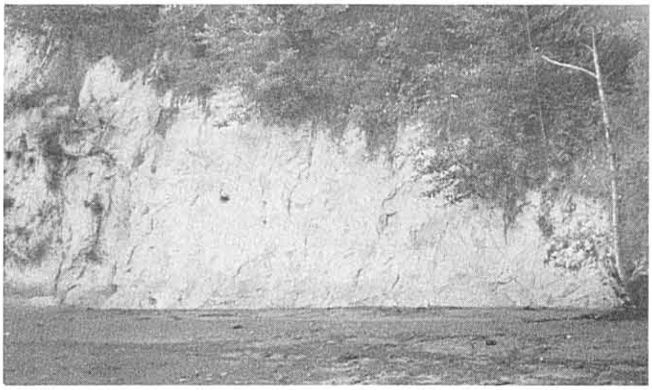
Because there are only a few exposures where the pre-Salmon Springs(?) deposits, undifferentiated can be examined, its character is known mainly from well logs. In most logs it is described as being composed of fine-grained materials, chiefly clay and fine sand, with occasional interbeds of coarser sands and gravels. In interpreting from drillers' logs it is sometimes impossible to separate soft sedimentary rocks of Tertiary Age from the overlying Pleistocene materials because of the similarity of the rock descriptions used. Many of the deeper wells in the report area have been drilled through the Pleistocene materials and continued into the Tertiary sedimentary rocks without any notation by the drillers of a change in formation. Drilling speed, which might give an indication of that break in lithology, was generally not recorded so that in many wells where the Pleistocene materials have been completely penetrated their thickness is not determinable from well logs.

Salmon Springs(?) Drift

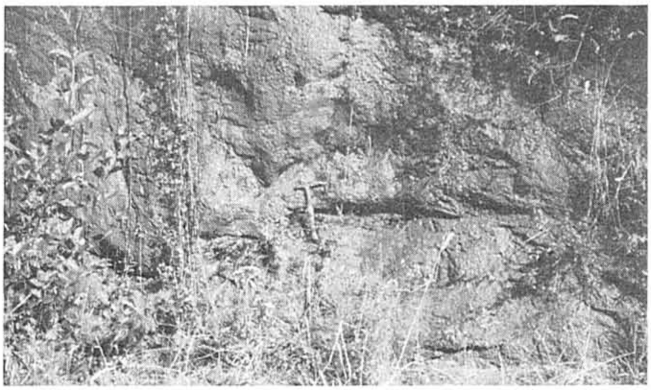
Lying unconformably upon the deeply eroded surface of the pre-Salmon Springs(?) deposits, undifferentiated, is a sequence of coarse, stream-laid gravels and sands with local occurrences of glacial till. These materials were correlated by Sceva (1957, p. 15) to the gravels studied and named the Orting gravel by Willis (1898). Because the gravels in the type locality near Orting in Pierce County grade upward into a fine-grained member (Willis, 1899), Sceva divided his Orting gravel in Kitsap County into a lower and an upper member, naming them the lower member and the Kitsap clay member of the Orting gravel (Sceva, 1957, p. 15-17). However, subsequent re-examination of the Pleistocene stratigraphy in Pierce County by Crandell and others (1958) has assigned Willis' Orting gravel to a much older glaciation than that responsible for deposition of these gravels in the Kitsap Peninsula area.

Two post-Orting, pre-Vashon glaciations have now been recognized and named by Crandell and others (1958) the Stuck and Salmon Springs glaciations. The type section of the Salmon Springs Drift has since been traced out to Browns Point northeast of Tacoma, and deposits of similar stratigraphic relationship have been subsequently mapped in the sea cliffs south of Tacoma by Walters and Kimmel (in preparation), and in Thurston County by Noble and Wallace (in preparation). These deposits are correlative with the so-called lower member of the Orting gravel named by Sceva (1957) in Kitsap County. The present writer has extended the mapping of these gravels into the southern part of the Kitsap Peninsula and has correlated these with similar deposits found in Thurston County by Noble and Wallace (in preparation). However, because of the lack of direct correlation by surface exposures with the type section in the Sumner-Orting area of Pierce County, the writer is in agreement with Noble and Wallace that it is advisable to correlate these sediments only tentatively and with reservation by naming them Salmon Springs(?) Drift.

The Salmon Springs(?) Drift is usually exposed at or slightly above the base of sea cliffs and primarily in the

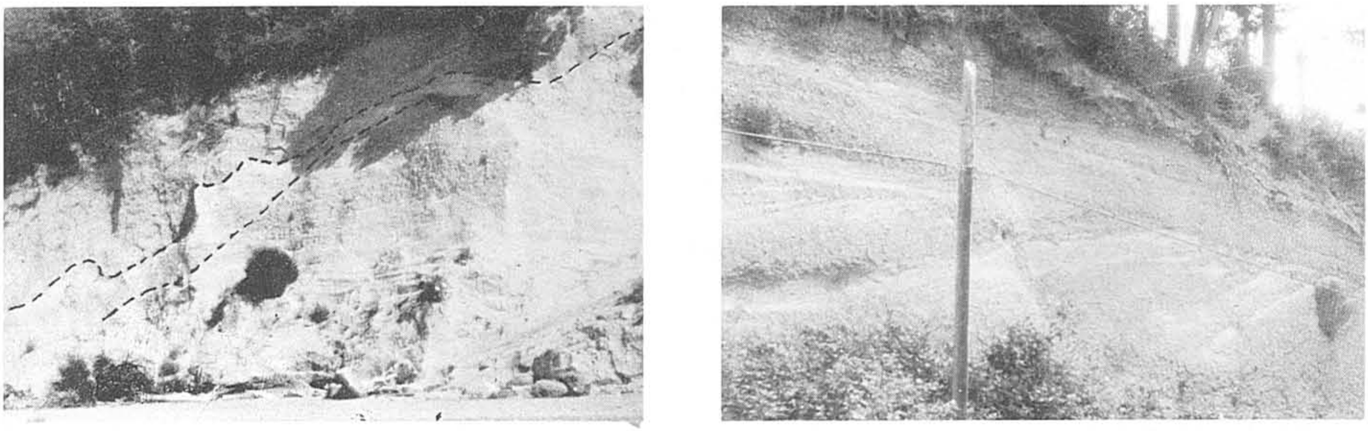


a. Base of beach bluff at Cove on Vashon Island, at 23/2E-26K.



b. Above road at 22/3E-19C on Vashon Island.

Figure 13. PRE-SALMON SPRINGS(?) DEPOSITS, UNDIFFERENTIATED.



a. Salmon Springs(?) Drift gravels underlying Colvos Sand and Vashon till at 20/2E-5C near Pt. Fosdick.

b. Exposure in roadcut at 22/2E-3M near Olalla, showing Salmon Springs(?) Drift gravels unconformably underlying Colvos Sand and Vashon advance gravels.

Figure 14. SALMON SPRINGS(?) DRIFT.

southern half of the report area, chiefly as a coarse-bedded gravel sequence with lenses of finer sands and some rare till pods. The upper surface of the drift is found at elevations of 10 to 30 feet above sea level and appears in some exposures to be conformably overlain by finer sediments, grading into the silts and clays of the Kitsap Formation. Locally peat beds are observed in what appears to be upper portions of the drift, but these may belong to the nonglacial Kitsap Formation. The base of the formation is seldom observed but is believed to extend to 200 or more feet below sea level where it fills the deeper valleys cut into the surface of the pre-Salmon Springs(?) deposits, undifferentiated. The only information on the thickness of the Salmon Springs(?) Drift comes from drillers' logs, hence it is frequently difficult to mark the depth at which these sediments overlie the older deposits. Although scattered exposures are found in Kitsap County proper, the surface of the Salmon Springs(?) Drift apparently has been slightly depressed northward in the Puget Sound basin, and most of the well-defined exposures are found in the southern part of the report area. The glacial drift forms a nearly continuously exposed basal part of the sea cliffs of the southern half of Longbranch peninsula and most of Anderson Island.

In many exposures the chief characteristics which distinguish these gravels from those of the Vashon Drift are the great degree of oxidation with lends to the formation a generally rusty orange coloration, and the inclusion of granules and lenses of pumice, which are not noticeable in the Vashon Drift. The oxidation is normally of a surficial nature only and the pebbles are not noticeably decomposed, although in many places the gravels have been sufficiently oxidized to become firmly cemented together, resulting in the formation of vertical cliff faces (Fig. 14a). The sediments were partially derived from granitic and metamorphic type rocks, signifying an origin in the northern Cascades and British Columbia. Where exposed in rare outcrops the glacial till is extremely compact, in contrast to the softer overlying Vashon till. The two tills are well exposed northwest of Green Point on the Horsehead Bay peninsula, at 21/1E-28D. Here the Salmon Springs(?) till is observed rising diagonally from the base of the sea cliff to attain an elevation of about 15 feet before being truncated by the younger Vashon till; the two till sheets are separated by a well-bedded sequence of reddish sands believed to be Colvos Sand.

Kitsap Formation

The Salmon Springs(?) Drift is overlain in most places by the Kitsap Formation which consists chiefly of clays and silts, with minor amounts of sands and gravels. Distinctive beds of peat and lignite occur at various intervals throughout the formation. The materials are of nonglacial origin. The presence of euhedral and subhedral hypersthene grains indicates a derivation from Mount Rainier and southern Cascade volcanic rock types.

Sceva (1957) assigned these deposits to the Kitsap clay member of the Orting gravel. However, these silts and clays are of nonglacial character, as opposed to the glacial outwash character of Sceva's lower member of the Orting gravel (herein named the Salmon Springs(?) Drift). Therefore, the writer, with concurrence by Noble and Wallace (in preparation), deemed it advisable to describe the Kitsap as a separate formation. The writer herewith proposes the name Kitsap Formation for this unit.

The type locality of the Kitsap Formation is a beach bluff exposure at 22/2E-9J, one-half mile north of Maplewood on the west shore of Colvos Passage. Here the formation appears to lie conformably above, and interfingers with, the Salmon Springs(?) Drift gravels. The presence of a peat-bearing silt stratum 1 to 4 feet thick about 15 feet below the top of the 55-foot sequence of predominantly reddish gravels suggests that early in the deposition of the Kitsap Formation there existed a stream depositional environment and/or the late stages of the Salmon Springs(?) Drift deposition included a lacustrine environment and a temperate climate. Such conditions would indicate a transition from a glacial to nonglacial environment at this location without an erosional interval.

In Thurston County to the south Noble and Wallace (in preparation) describe similar deposits of peat-bearing silt overlying gravels of Salmon Springs(?) Drift, between Butterball Cove and Hogum Bay along Nisqually Reach. Here is exposed about 60 feet of horizontally-bedded brown to gray silt and clay overlying 4 feet of rusty gravels just above beach level. At least three peat-bearing strata are observed in this exposure. The upper surface of the formation is generally obscured by a dense cover of vegetation.

Several sections of well exposed Pleistocene deposits were measured in the southern part of the report area and show the relationship of the Kitsap Formation to the underlying Salmon Springs(?) Drift and the overlying Colvos Sand as follows:

19/1W-2B: South end of Longbranch peninsula at Devils Head.

Rock unit	Thickness
Vashon till ---------------------------	(top of bluff)
Colvos Sand: sand, brown, medium-grained --------------------------	10'
Kitsap Formation: silt, peat-bearing, with vivianite inclusions ------------	12'
Salmon Springs(?) Drift: gravel and sand, rusty ------------------------	20'

From this point northwesterly along the west shore of Longbranch peninsula the Salmon Springs(?) Drift decreases in grain size, the Kitsap Formation thins and disappears, and farther north it is difficult to distinguish the boundary between the Salmon Springs(?) Drift and the Colvos Sand except by a slightly more oxidized coloration of the former.

19/1E-20B: South end of Anderson Island.

Rock unit	Thickness
Vashon till ---------------------------	3'
Colvos Sand: sand, brown, medium-grained --------------------------	10'
Kitsap Formation: silt, peat-bearing -----	3'
sand, silty ------------------------	8'
Salmon Springs(?) Drift: gravel, rusty ---	10'
silt, clay, peat-bearing -------------	2'

Immediately west of this exposure thin strata of younger clay of glacial Lake Russell overlie the Vashon till.

21/2E-30Q: West shore, entrance to Wollochet Bay.

Rock unit	Thickness
Vashon till --------------------------	12'
Colvos Sand: sand, gravel ------------	20'
Kitsap Formation: clay, peat-bearing ---	3'
Salmon Springs(?) Drift: gravel, rusty --	20'

20/1E-18N, P: West shore of Pitt Passage, northeast of Mahnckes Point.

Rock unit	Thickness
Vashon till --------------------------	20'
Colvos Sand: sand, brown, medium-grained --------------------------	15'
Kitsap Formation: clay, silt, peat-bearing --------------------------	15'
Salmon Springs(?) Drift: sand, brown, medium-grained ------------------	30'

Except for interbed of Kitsap Formation here, Salmon Springs(?) Drift would have been mapped as Colvos Sand.

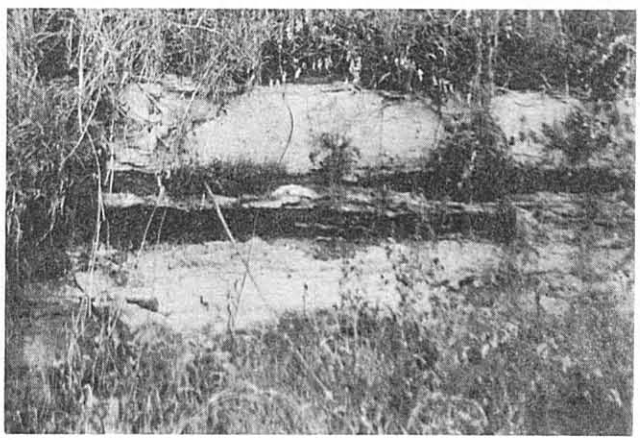
22/2E-9J, K: West shore of Colvos Passage, one mile south of Olalla.

Rock unit	Thickness
Colvos Sand: sand, reddish-brown, with silt -------------------------	40'
clay, blue-brown, finely bedded -----	43'
Kitsap Formation: silt, with 2" peat stratum at top---------------------	2'
Salmon Springs(?) Drift: gravel, red -----	15'
peat ---------------------------	1'
clay, blue -----------------------	3'
gravel, red ----------------------	35'

This section shows the transition of gravels, clay, silt and peat at contact between the Salmon Springs(?) Drift and the Kitsap Formation.

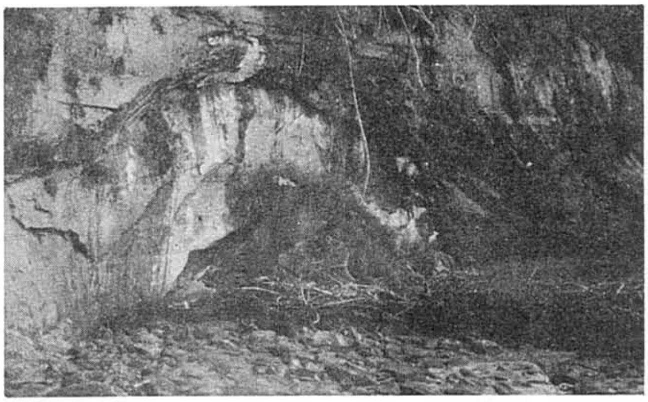
The Kitsap Formation is well exposed along the base and lower parts of sea cliffs throughout the report area. Well-laminated peat beds form noticeably resistant strata in many exposures and some are observed to crop out from beneath beach gravels as at 22/2E-15R (Fig. 15a). These peat strata are particularly well exposed in the Kitsap Formation along the highway west of Port Orchard at 24/1E-27P (Fig. 15b). Here two or three relatively thick strata are exposed at road level and above, beneath a thick sequence of well-bedded blue clays and silts.

a. Peat stratum exposed in beach gravels south of Sandford Point on Vashon Island at 22/2E-15R.

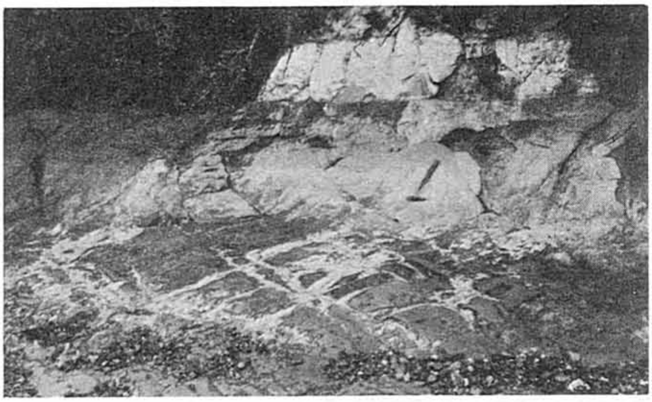


b. Peat strata within silts and clays, exposed along highway west of Port Orchard, at 24/1E-27P.

Figure 15. KITSAP FORMATION

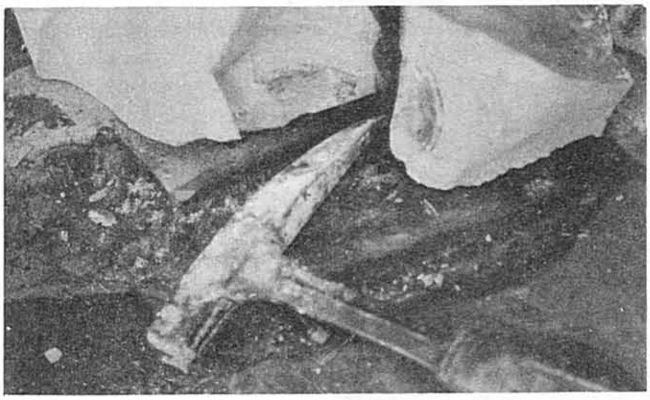


a. Massive 20-foot silt bed, showing spalled off blocks lying on beach.



b. Base of silt bed, showing wave-eroded character of hard materials, also joint pattern of mudcracks exposed at beach level.

Figure 16. KITSAP(?) FORMATION
Exposure of massive, nearly shale-hard stratum of silt at base of beach bluff on Vashon Island at 22/2E-2Q. Although mapped as Kitsap Formation, this material may be of considerably greater age.



c. Fragment of silt, showing fossel clam replaced by vivianite.

The Kitsap Formation is normally well-stratified and in most places the clay strata are finely laminated in contrast to the thicker, more massive and predominately contorted clays of the pre-Salmon Springs(?) deposits, undifferentiated. In some localitites, however, differentiation between the older clays and the Kitsap Formation clays is difficult, and only a detailed petrologic-mineralogic study will separate the glacial and nonglacial character of each. In some cases the areas mapped on Plate 1 as the Kitsap Formation may actually represent the older materials. For example, one mile north of Lizabuela on Vashon Island (22/2E-2Q), exposed at beach level is a massively bedded, horizontal stratum of brownish to gray silt and clay. The material is nearly shale-hard and numerous blocky fragments have spalled off the outcrop and lie on beach below (Fig. 16a). In places where the silt and clay surface has been eroded to beach level a joint pattern of mudcracks is observed (Fig. 16b). Of particular interest are the numerous small brilliant blue vivianite inclusions, some of which have replaced fossil fresh-water clam shells (Fig. 16c).

The thickness of the Kitsap Formation varies greatly throughout the report area, from less than a foot to more than 200 feet, with the top of the formation ranging from below sea level to 200 feet or more above sea level. As shown in the diagrammatic sections on Plate 1, the thickness of the Kitsap Formation has probably been exaggerated, owing to inclusion here of older undifferentiated clays and silts. Conversely, in some areas where sands and gravels occur in the lower part of the formation these have been mapped with the Salmon Springs(?) Drift. Likewise, where the upper part of the Kitsap Formation has graded into sand, this has been mapped as Colvos Sand.

Because of the widespread distribution of these peat-bearing nonglacial sediments throughout the Puget lowland, the Kitsap Formation has been considered useful in stratigraphic correlation of nonglacial materials in the report area. However, the time correlation between peat beds of apparent stratigraphic similarity has been occasionally subject to revision owing to both a variation in dates obtained from a given bed and a possible variation in methods of analyses between the several laboratories conducting the tests. For example, recent redating of peat collected at Johnson Point in Thurston County gives an age greater than 42,000 years, whereas an earlier analyses gave a date of 27,900 years (Dorn and others, 1962). Peat beds from an apparently similar stratigraphic horizon in Seattle have been dated as 20,300 years (Stark and Mullineaux, 1950), and even younger dates of 15,000 years have been subsequently obtained in Seattle (Mullineaux and others, 1965). Further north, in the Strait of Georgia lowland, peat and wood collected from the Quadra Formation, believed to be stratigraphically correlative to the Kitsap Formation, have been dated between approximately 25,000 and 35,000 years.

Unnamed gravel

Associated with the finer floodplain deposits of the Kitsap Formation, and found exposed along the bluffs of the western upland, is a thick sequence of poorly bedded rust-colored gravel and coarse sand. Previously mapped with the Vashon advance outwash by Sceva (1957), these generally coarse sediments consist predominantly of basalt, argillite, sandstone and slate pebbles, derived almost entirely from rocks of the Olympic Mountains. Occasionally a granitic pebble of northern origin is found, undoubtedly a re-worked constituent of an earlier glacial drift. In places the gravel is considerably weathered and decomposed, and disintegrates under the blow of a hammer, while in other outcrops it is well cemented and conglomeratic, and at beach level has been eroded by wave action to form overhanging alcoves. Interbeds of reddish to yellowish silt and clay with some peat strata indicate the gravel's nonglacial character and relationship to the more widespread Kitsap Formation.

Although bedding is generally poorly defined, some exposures visited on the west shore of Hood Canal across from the report area (Fig. 17) show an eastward dipping bedding that suggests the gravel's origin as fluviatile or glaciofluviatile material deposited as alluvial fans extending beyond the foothills of the Olympic Mountains. The reddish gravel has also been found by Noble (oral communication) to be widespread as a major depositional unit throughout the lowland of southern Mason County. Until a more detailed study has been made of this formation, it is in this report designated the unnamed gravel.

Figure 17. UNNAMED GRAVEL, exposed on west shore of Hood Canal, Mason County. Deltaic bedding dips eastward from front of Olympic Mountains. Vashon till overlies gravel in upper right corner of photograph.

Vashon Drift

The Vashon Drift was named by Willis (1898) and includes the extensive till sheet and associated outwash sands, gravels, and clays deposited in the Puget Sound lowland during the advance and recession of an ice lobe originating in the north during the latest major glacial epoch.

Vashon outwash is material which was deposited beyond the ice front by glacial meltwater streams. Near the ice front, poorly sorted, roughly stratified gravel and coarse sand was deposited while at greater distances from the glacier front finer-grained, more evenly stratified sands, silts and clays were deposited. Material deposited ahead of the advancing glacier and subsequently over-ridden by the ice is termed "advance outwash," while material deposited during the recession of the glacier and consequently laid down across the till surface exposed by the retreating ice is termed "recessional outwash." These two outwash units are usually separated by the intervening stratum of glacial till, normally a mixture of gravel and cobbles in a matrix of clay and silt, laid down as a basal deposit beneath the moving ice sheet.

Included with the Vashon Drift is a younger clay deposited during late Vashon time in glacial Lake Russell (Bretz, 1913).

Because present evidence suggests that the Colvos sand was laid down as a proglacial deposit of the Vashon ice sheet, it is included under the discussion of the Vashon Drift.

Colvos Sand

The nonglacial peat-bearing clays and silts of the Kitsap Formation are overlain by a thick sequence of fine-grained, well sorted sands. Deposits range from finely laminated varved clays and silt, usually found at the base of the formation, to thick, massive strata of sand, with local strata and lenses of coarse sand and gravel. Current and deltaic bedding are present in some places. Some exposures exhibit varying gradations from sand to gravel, while others show well-bedded strata and lenses of silt and clay.

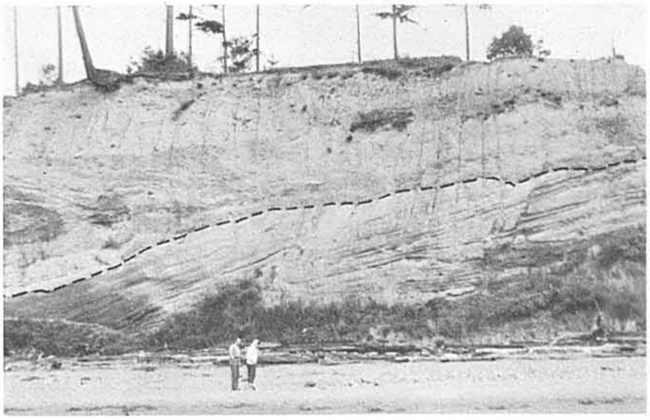
As discussed earlier, the sand sequence was believed by Sceva (1957) to be correlative to the Puyallup Sand, a formation first described in the Tacoma area by Willis (1898). Subsequent studies have found this sand to be of much younger age than that of the originally described Puyallup Sand, and also to be of glacial derivation as opposed to the nonglacial origin of the Puyallup Sand.

The thick sand sequence is prominently displayed in many sea cliffs throughout the report area (Fig. 18a) and is believed to be correlative to many similar thick sand units exposed along the waterways in other parts of the Puget Sound lowland, such as the upper part of the Lawton Formation described in the Seattle area by Stark and Mullineaux (1950) and the Esperance sand described in Snohomish County by Newcomb (1953). As the sand has been only tentatively correlated to the previously named units found elsewhere, the writer proposes that, because the sand is well exposed in the sea cliffs along Colvos Passage, the name Colvos Sand be applied to this unit.

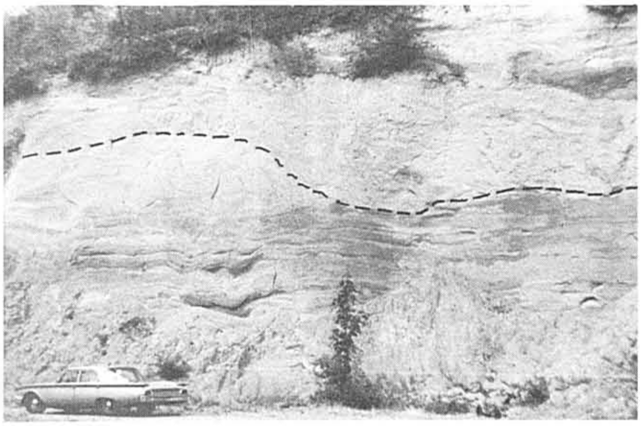
At many places along both shores of Colvos Passage the Colvos Sand exhibits its gradation from blue glacio-lacustrine clays at the base, usually near beach level, upward into silt and sand. At 23/3E-7L-M, near the north end of Vashon Island, a road descending from the upland to Sandy Beach passes through excellent exposures of the entire sequence from Vashon till to the clays at the base of the Colvos Sand and silts of the Kitsap Formation. From near beach level to an altitude of about 250 feet is exposed a thick sequence of well-bedded, soft brown sand. The top of the sand grades upward into coarser strata of sand and gravel of the Vashon advance outwash, above which lies Vashon till. The contact between the Colvos Sand and advance outwash is conformable and gradational, indicating an environment of continuous, uninterrupted deposition at this location.

Although in some exposures the Colvos Sand is unconformably overlain by gravels of the Vashon advance outwash (Fig. 18b) and in some places is directly overlain by Vashon till (Figs. 18c, 18d), the erosional interval was evidently of short duration and local in extent in the Kitsap Peninsula. Some exposures display injection of underlying clays and silts into the Colvos Sand. This is well illustrated at 28/2E-18, south of Foulweather Bluff (Figs. 18e, 18f), where strata composed of dark clays and lighter silts have been

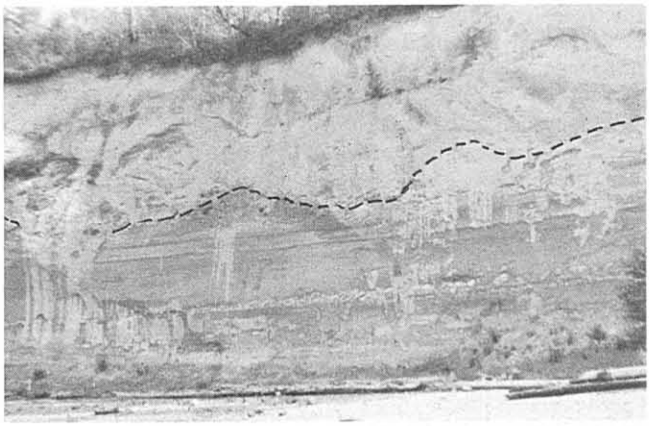
a. Thick exposure of Colvos Sand in sea cliff at 28/2E-19J.



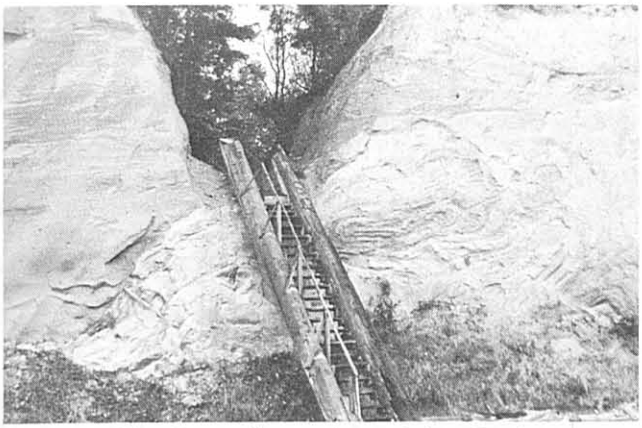
b. Colvos Sand unconformably overlain by Vashon advance outwash and till, exposed in sea cliff at 28/1E-13B.



c. Bluff near Annapolis at 24/1E-25M, showing Colvos Sand overlain by Vashon till.



d. Sea cliff at 28/2E-18D, showing Colvos Sand overlain by Vashon till. Lower part of cliff shows fragments of Kitsap Formation clays aligned in bedding plane.



e. Clay injected upward into Colvos Sand, exposed in sea cliff at 28/2E-18Q.

f. Detailed view of clay injected into horizontally bedded Colvos Sand.

Figure 18. COLVOS SAND. Several exposures showing relationship to overlying and underlying depositional units.

contorted beneath horizontally bedded sand. The clays involved were probably laid down in lakes early in the period of deposition of the Colvos Sand. According to Bretz (1913, p. 185) such distortion of the clay beds without noticeable deformation of overlying beds of sand might be the result of vertical compression and a quicksand-type environment during the deposition of the sand.

The thickness of the Colvos Sand varies throughout the report area from a few feet to over 300 feet, with the base of the unit usually found near sea level.

The Colvos Sand is in some upland areas difficult to distinguish from Vashon recessional outwash sands, and, as mapped on Plate 1, the Colvos Sand may include Vashon recessional outwash materials. Where Vashon till is not present above the Colvos Sand to distinguish it from Vashon recessional outwash sands, the following criteria have been used by the writer to identify the Colvos Sand: (1) greater compaction of the sand, as opposed to the comparatively loose consolidation of the recessional sand; (2) presence of a thin surficial zone of fissile clay at top of sand, indicating the unit was probably affected by the subsequent overriding of the Vashon glacier; and (3) presence of occasional erratics or lag gravels upon the surface of the Colvos Sand. Otherwise the sands have been mapped locally as Vashon recessional outwash sands. Areas in the Kitsap Peninsula where such upland exposures of Colvos Sand and/or Vashon recessional outwash sands are found are the relatively broad upland valleys listed below according to geographic provinces:

- Northern upland: valley heading south end of Port Gamble bay southwest of Striebels Corner; upland north of Indianola.
- Central upland: Barker Creek valley; Claire Marsh-Meadowdale valley; upland east of Tracyton.
- Southern upland: uplands above Port Orchard and Annapolis; Burley Creek-Blackjack Creek valleys; Olalla Creek-Long Lake-Curley Creek valley; Minter Creek valley; Gorst Creek-Union River trough.
- Vashon Island: upland near Point Beal; north half of Burton peninsula.
- Gig Harbor peninsula: McCormack Creek valley; Artondale Creek valley; Raft Island and south along southwest upland of peninsula.
- Longbranch peninsula: upland alongside main north-south road in north half of peninsula; valley heading north from Whitman Cove.

Advance Outwash

As mapped on Plate 1, the advance outwash consists chiefly of the gravels and coarse sands that lie beneath the Vashon till cap and above the finer sands mapped as Colvos Sand. Many deposits of advance outwash gravels obscure underlying materials by forming a thin veneer along valley sides. These may lead to a misconception as to the character of the materials forming the uplands. In these areas it is often necessary to study drillers' logs to interpret the probable geologic sequence. A typical exposure of Vashon advance outwash beneath a till capping is a sequence of poorly sorted gravels at the top grading downward into better sorted and stratified gravels and sands, with locally a lense or stratum of lacustrine silt or clay (Fig. 19).

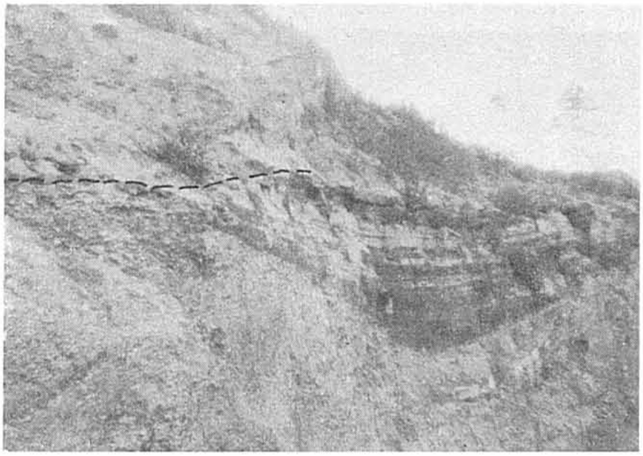


Figure 19. VASHON ADVANCE OUTWASH. Gravel pit exposure at 24/1E-34K south of Port Orchard, showing Vashon till overlying advance outwash gravels and a lense of bedded sand and silt.

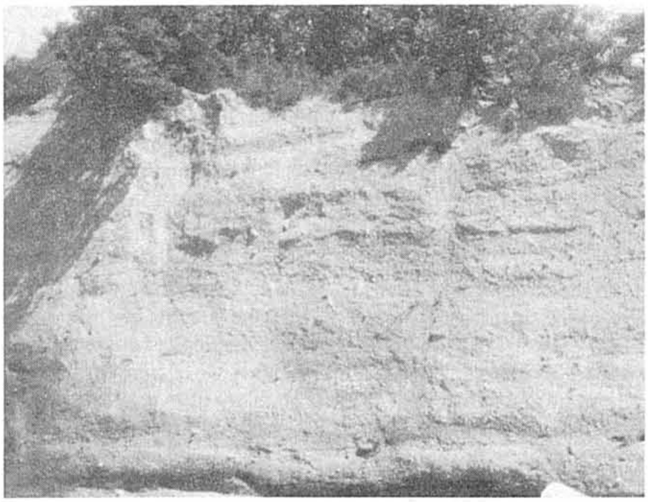
Till

Till is a primary deposit associated with each glacial advance. Till is normally a gray to bluish-gray compact and unsorted mixture of cobbles and pebbles in a binder of silt and clay. This material was "smeared" along the ground by the tremendous pressure produced by the weight of the ice. This basal deposit of the ice characteristically forms a capping on the topography over which the ice sheet advanced. The normally compact nature of the glacial till has given to it the local name of "hardpan." It is commonly so hard that blasting is required during the construction of dug wells, although in some places where the ice rode over sandy materials, such as the Colvos Sand, the till may be sandy and relatively friable.

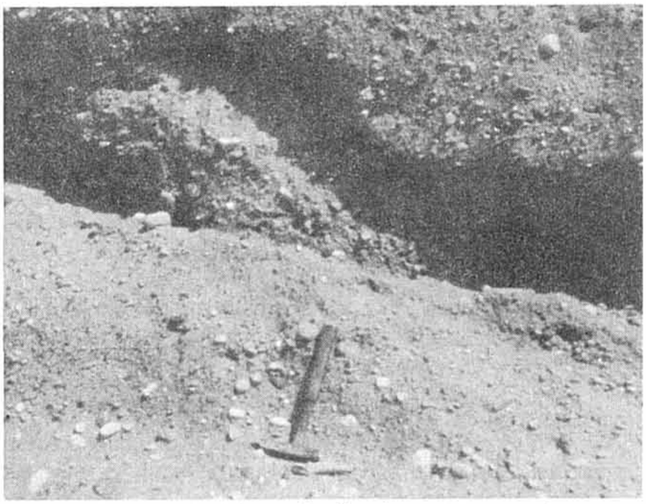
Observed exposures of Vashon till vary in thickness from less than a foot to more than 50 feet. The nature of till deposition beneath moving ice has generally resulted in greater thicknesses being laid down on the southerly or "lee" slopes. This is particularly noticeable in the great thicknesses of till found exposed on many south-facing sea cliffs. In many such exposures the entire cliff is composed of till (Fig. 20). In contrast, most north-facing sea cliffs consist primarily of older materials capped by a thin till sheet.

The weight and pressure of the moving ice on underlying sediments have caused their deformation in some places. At 22/2E-14D on Vashon Island south of Lizabeula a thick sequence of well-bedded Colvos Sand exhibits a gradually steepening dip until it is nearly vertical as it parallels similarly upturned silt and clay strata of the pre-Salmon Springs(?) deposits. This structure is a result of the great force exerted by the overriding Vashon glacier.

Marine fossils were found by Sceva (1957) in the till in the low sea cliff along Skunk Bay at 28/2E-18H southeast of Foulweather Bluff. The writer examined small fragments of marine shells in the same general location and it was apparent that such fragments were derived from older underlying sediments of pre-Vashon age. It should be noted that in the northern part of the Puget Sound lowland, near Bellingham in Whatcom County, marine fossils have been found intact by Easterbrook

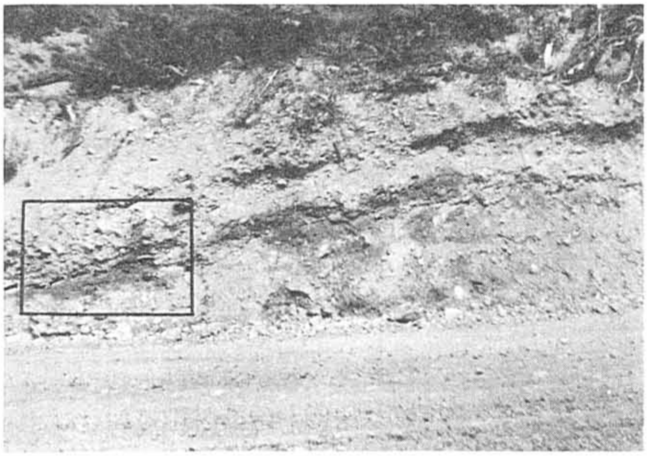


a. Till exposed in 50-foot sea cliff at 21/1E-27G, west of Fox Island Bridge.

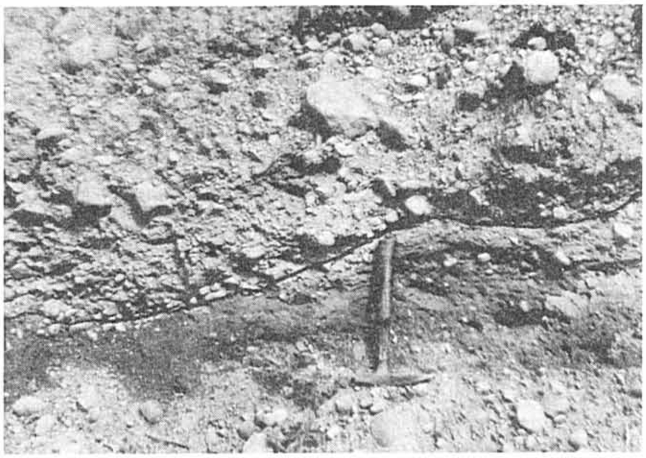


b. Detailed view of till, showing unsorted mixture of coarse pebbles in silt and clay.

Figure 20. VASHON TILL



a. Ablation till overlying till, seen in road cut at 24/2W-32Q.



b. Detailed view of outlined area.

Figure 21. VASHON ABLATION TILL

Figure 22. GLACIAL ERRATIC. Greenstone boulder near outlet to Lake Tahuya at 24/1W-20C.

(personal communication). These occur in two glacio-marine drift units subsequently assigned by Easterbrook to the Bellingham and Kulshan glaciomarine drifts (Armstrong and others, 1965).

Vashon till is composed of a great variety of rock types which indicate their derivation from rocks of the northern Cascades and British Columbia. Locally, in areas south of the Green Mountain-Gold Mountain upland, the till contains basalt fragments derived from the Tertiary volcanics forming those hills. In areas adjacent to outcrops of the Blakeley Formation fragments of those sedimentary rocks are incorporated in the till.

Vashon till is normally unweathered and fresh in appearance in most exposures, with no chemical or mechanical decomposition of individual components, although in places springs and ground-water seepage have given the till a rusty oxidation coating.

Vashon till is overlain in some broad upland areas by a few feet of ablation till—the part of the glacier's rock load deposited as the ice melted. It is less compact than the basal till and many of the finer particles of silt and clay have been washed away by meltwater. Large upland areas, such as the Tahuya peninsula of the western upland and the western part of the southern upland, are overlain by ablation till deposits of loose, unsorted, coarse gravels (Fig. 21), and occasional erratic boulders (Fig. 22).

Recessional Outwash

Vashon recessional outwash occurs in the report area chiefly as a mantle of sand and gravel lying on the till (Fig. 23). In many places these deposits are not sufficiently thick or extensive to map and have been included with the Vashon till. Thicker deposits occur in several meltwater channels and depressions in the uplands and were separated into two units consisting of recessional gravels(Qvr) and recessional sands (Qvrs), the latter including Sceva's Gorst Creek outwash (1957) and probably including some Colvos Sand.

The Gorst Creek outwash was named by Sceva (1957) to include a deposit of fine-grained, well bedded sand that accumulated in the Union River-Gorst Creek valley during the waning stages of the Vashon glaciation. The sand was evidently deposited under quiet water conditions and covered many large blocks of Vashon ice. Subsequent melting of the glacier fragments resulted in the development of kame and kettle topography, and local slump-deformation of the strata.

As discussed earlier, the recessional outwash sands as they occur in broad upland valleys are difficult to distinguish from the underlying Colvos Sand and, as mapped on Plate 1, the names of the two units may in some places be interchangeable. Likewise, the coarse, poorly bedded recessional outwash gravels are in many places indistinguishable from the ablation till and are mapped with the till on many upland areas.

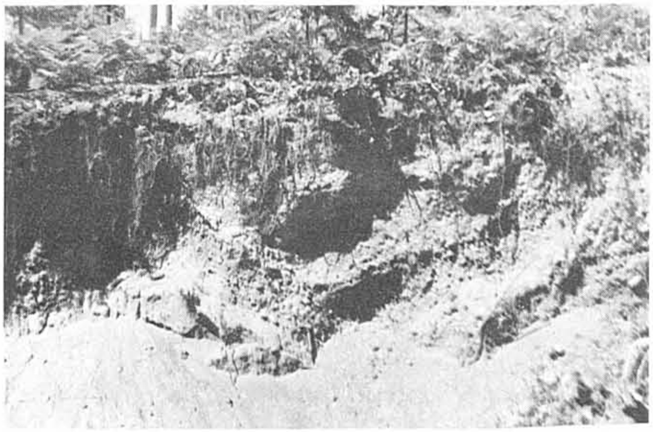
Younger Clay

Exposed only in a few places in the Kitsap Peninsula area is a well stratified unit of clay which is believed to have been deposited in glacial Lake Russell (Bretz, 1913) at the close of the Vashon glaciation. The 4- to 6-inch beds of buff to blue-gray clay overlie Vashon till and recessional outwash deposits. Although found as high as 100 feet above sea level in small isolated exposures throughout the report area, this younger clay has been mapped on Plate 1 only in the Ora Bay area of Anderson Island and near Hansville in the northern part of the Kitsap Peninsula.

Recent Alluvium

Sedimentary materials continue to be deposited through the present day. Postglacial depressions and ponds have been the sites for deposition of silt, clay and peat. Streams have deposited sand and silt in valleys and across growing deltas at the heads of numerous Puget Sound embayments.

a. Deltaic bedding in recessional outwash overlying till at 22/2W-18P in bluff along Hood Canal.



b. Recessional gravel strata distorted by slumping, roadcut at 23/2W-7F.

Figure 23. VASHON RECESSIONAL OUTWASH

Table 2. A SUMMARY OF STRATIGRAPHIC UNITS OF PLEISTOCENE AGE IN THE KITSAP PENINSULA.

Map Symbol	Stratigraphic unit		Character and extent	Thickness in feet	Water-bearing properties
Qvr	Vashon Drift	recessional outwash	Discontinuous bodies of unconsolidated silt, sand, and gravel. Deposited by meltwater of Vashon glacier.	0-100	May yield small to moderate supplies of ground water for domestic purposes where deposits have considerable thickness.
Qvt	Vashon Drift	till	Extensive till sheet which mantles most of upland areas. Till varies greatly in compaction and composition.	0-80	Essentially impervious, but may yield small supplies of perched ground water.
Qva	Vashon Drift	advance outwash	Discontinuous bodies of unconsolidated silt, sand, and gravel. Deposited by meltwater streams from advancing Vashon glacier.	0-50	Yields moderately large to large quantities of water where deposits extend below water table.
Qc		Colvos Sand	Principally stratified sand. Contains irregular lenses of fine gravel, and thin strata of clay and silt. Underlies Vashon Drift throughout most of Peninsula.	0-300	Primary formation presently utilized by drilled wells where base below water table. Sand yields domestic quantities; gravel strata yield moderately large quantities.
Qg	unnamed gravel		Poorly bedded, pebble to cobble gravels. Primarily rust-stained, some decomposed, some cemented. Includes silt and peat beds.	0-400+	Domestic supplies obtained from unconsolidated gravels near sea level in Tahuya area of Hood Canal.
Qk	Kitsap Formation		Principally well-bedded silt and clay, with occasional lenses of sand and gravel. In places contains peat beds.	0-200+	Gravel lenses yield small quantities of water, but formation normally of low permeability and yields little or no ground water.
Qss	Salmon Springs(?) Drift		Principally stratified sand and gravel. May be stained buff or orange-colored in outcrop. Contains some silt, clay and till strata.	0-300+	Yields large quantities of ground water, frequently under artesian pressure.
Qpu	pre-Salmon Springs(?) deposits, undifferentiated		Principally massive blue clay and silt. Deformed in most places. Contains till, volcanic ash, peat or lignite, sand, and some gravel strata. Top of formation usually below sea level.	0-600+	Clay, silt and till strata yield little or no ground water. Gravel may yield small to moderate quantities. Successful wells are few.

GROUND WATER

The general features of ground-water occurrence, including a definition of ground water and a discussion of the water table, unconfined and confined ground water, ground-water recharge and discharge, hydraulics of a well, and salt-water contamination are given on Plate 2.

OCCURRENCE OF GROUND WATER WITHIN STRATIGRAPHIC UNITS

TERTIARY ROCKS

Volcanic Rocks

Owing to their dense and extremely impermeable character the volcanic rocks are not important as aquifers and no wells in the report area are known to develop adequate supplies of ground water from these rocks.

Sedimentary Rocks

Many deep wells have been drilled into the sandstone, shale and conglomerate of the Tertiary Blakeley Formation, but most of these have been unsatisfactory as to yield and quality of water obtained. Two wells drilled by the U.S. Navy at the south end of Bainbridge Island penetrate this formation. Well 24/2E-10R, 1700 feet deep, reportedly yielded only small quantities of saline water. Well 25/2E-36N, 1403 feet deep, yielded less than 15 gallons per minute with several hundred feet of drawdown, and the water was of poor quality. Wells drilled near the Watauga Beach community at Point Glover have experienced similar results. Well 24/2E-9G, 400 feet deep, had a drawdown of more than 200 feet in 12 hours of pumping only 2½ gallons per minute, and the water was also undesirably high in mineral content. Well 24/2E-9L, 184 feet deep, flowed several gallons a minute but the water was brackish and not usable. Several other wells in this area produced barely minimum domestic supplies, although well 24/2E-9M, 200 feet deep and entirely in the Blakeley Formation, produced sufficient water to supply several families.

QUATERNARY ROCKS

Pre-Salmon Springs(?) Deposits, Undifferentiated

These sediments are not normally to be considered an important source of ground water in the Kitsap Peninsula because of their generally low permeability. A few wells drilled into the coarser sediments at depth have produced moderate to large quantities of water; however, the casings of several of the deep wells are perforated in so many horizons that it is uncertain whether water is being obtained from these older materials or from overlying aquifers. Owing to the difficulty in distinguishing from well logs between the Salmon Springs(?) Drift materials and the older deposits of sand and gravel, it is not certain which of the two formations might be producing the main water supply.

Deep sand and gravel strata interbedded with clay and silt are the chief aquifers in these older materials; some are reported to occur as much as 1000 or more feet below sea level. Wells developing water from these aquifers generally have low specific capacities and in many cases sand flowing into the wells is a problem. However, in a few cases wells penetrating the upper finer materials which serve as confining layers have obtained water under artesian flow conditions from the deeper coarser gravel materials. Such flowing wells have been drilled near Burley at 22/1E-1N, 11A, and 12D, two of which flowed several hundred gallons per minute when drilled. Flowing wells were also drilled near Keyport at 26/1E-36N, and along the shores of Sinclair Inlet in the Bremerton-Port Orchard-Annapolis area (wells 24/1E-23B with a flow of 20 gallons a minute, 24/1E-25E with a pumping capacity of 1700 gallons a minute, and 24/1E-33L with a pumping capacity of 3000 gallons a minute). Several wells that were perforated in only the deeper horizons (wells 24/1E-25K and 36F) yielded several hundred gallons a minute at the time of drilling but the yields soon diminished to the extent that the wells were no longer usable.

The construction of deep wells in the pre-Salmon Springs(?) deposits, undifferentiated, entails considerable risk of failure as the formation is principally fine-grained, the permeable strata are not continuous and sustained production can be developed only in aquifers that have free access to overlying formations. It is advisable to thoroughly test for yield all overlying permeable materials before attempting to drill deeper into the older sediments.

Salmon Springs(?) Drift

Because the coarse gravels of the Salmon Springs(?) Drift lie at or slightly above sea level and below the regional water table in most of the Kitsap Peninsula, it is probably the most important potential source of ground-water supplies for future development in the report area. Lying below the fine-grained Kitsap Formation, it is also capable of yielding large quantities of artesian ground water.

Among the wells which show capability of yielding large supplies of ground water from the Salmon Springs(?) Drift are those listed below:

- 21/2E-8C: Town of Gig Harbor; 340 gpm from 200 feet below sea level.
- 22/1E-12N: E. Black, near Burley; 600 gpm artesian flow from 200 feet below sea level.
- 24/1E-5E: Erland Point Water Company; 500 gpm from 30-150 feet below sea level; initially had artesian flow.
- 24/2E-7D: North Perry Water District; 800 gpm from 50-60 feet below sea level.
- 26/1E-32M: U.S. Navy Ammunition Depot; 550 gpm from 75-300 feet below sea level.
- 27/2E-7A: Town of Port Gamble; 150 gpm from 100 feet below sea level.

As noted under the discussion of the pre-Salmon Springs(?) deposits, undifferentiated, some of the above listed wells may also be obtaining water from these older materials, or from both formations.

Kitsap Formation

The characteristically fine-grained sediments that compose most of the Kitsap Formation make the sequence unimportant as an aquifer. However, the impermeability of the formation makes it important as an aquiclude, both as a base for perched, unconfined ground water and as a confining layer above the Salmon Springs(?) Drift gravels. The relatively thin and discontinuous sand and gravel lenses in the formation will yield small supplies of ground water, but the clay and silt strata yield little or no water.

In inland areas the Kitsap Formation's relationship with underlying materials must be inferred only from drillers' logs, and it is usually impossible to differentiate between the sands and gravels of the Kitsap Formation and similar materials in either the Salmon Springs(?) Drift or the pre-Salmon Springs(?) deposits. Likewise, where the finer materials of the Kitsap Formation directly overlie the finer materials of the pre-Salmon Springs(?) deposits, it is difficult to separate the two formations. Where these fine materials grade together to form a thick sequence, wells may be drilled to considerable depth without successfully penetrating any coarse water-bearing sands and gravels. For that reason some risk is involved in drilling through the Kitsap Formation in search of the underlying Salmon Springs(?) Drift aquifers. Generally, if the Salmon Springs(?) Drift is present, it is usually encountered within 70 to 150 feet below the top of the Kitsap Formation.

Unnamed Gravel

The unnamed gravel is the primary aquifer underlying the beachfront properties along Hood Canal in the Tahuya area. Here the gravel has yielded domestic supplies to wells drilled to depths of 30 to 40 feet, with the water levels standing slightly above sea level. Salt-water contamination in this area could pose a problem if wells were pumped at excessive rates. The rust-stained appearance of the gravel in many exposures suggests that ground water derived from the formation may contain undesirable amounts of iron.

Vashon Drift

Colvos Sand

The Colvos Sand is the most widely developed source of ground water for domestic supplies in the report area, with the coarser sands and gravels forming the chief aquifers. The regional water table lies above the base of the formation in most places and most wells obtain water under unconfined water-table conditions. Locally, interbedded clay and silt, and overlying till serve as confining and perching strata to small bodies of ground water.

The typical domestic well obtaining water from the Colvos Sand has a 6-inch open-bottom casing, is drilled to a depth of 100 to 150 feet, and will produce 15 to 20 gallons a minute. Proper screening and development of such wells may result in production of 50 or more gallons a minute. Among wells that show capability of yielding moderate to large supplies of ground water from the Colvos Sand are the following:

- 21/2E-21C: Westbridge Estates Water Company; 300 gpm from 255-foot well.
- 22/1W-11J: Union Oil Company; 200 gpm from 352-foot well.
- 23/1W-11J: Kitsap County Airport; 200 gpm from 150-foot well; abandoned after spring supply located nearby.
- 23/2W-13H: State Department of Institutions; 250 gpm from 180-foot well; drilled to 210 feet but pulled back and filled to 180 feet.
- 23/1E-7D: Sunnyslope Water Assn.; 200 gpm from 220-foot well.
- 23/1E-14A: C. Sowa; 100 gpm from 145-foot well.

Advance Outwash

Vashon advance outwash deposits are highly permeable but usually occur above the regional water table. Where these materials occur in considerable thickness and extend below the water table moderately large supplies of ground water may be obtained. Where till overlies these saturated materials, confined ground water may also be obtained. In the till-mantled Clear Creek valley north of Silverdale several wells tap confined ground water zones in the advance outwash sands and gravels.

Till

Because of its compact, dense, and highly impermeable character, till cannot be considered as a water-bearing unit except where more permeable sand and gravel lenses occur within it. Wells tapping such limited aquifers are usually large diameter dug wells, useful only for small domestic supplies, and frequently such wells go dry during the late summer months.

The primary value of the glacial till is in its serving as an impermeable base for perched ground water bodies and as an impermeable cap for confined ground water. Where the till "drapes" or caps a sloping upland surface it also reduces the loss of ground water to springs.

Recessional Outwash

Where the recessional outwash deposits occur in considerable thickness and areal extent in upland valleys, small to moderate supplies of ground water may be obtained. In places where the coarser sands and gravels extend below the regional water table, they are capable of yielding moderate to large supplies. The fine-grained character of some deposits prevent them from being highly productive; these sandy deposits are found in the valleys of Union River, Gorst Creek, Olalla Creek, Long Lake, Curley Creek, Burley Creek, Blackjack Creek, and Minter Creek. Small domestic supplies are obtained from large diameter wells dug into the saturated portions of these sands.

The recessional outwash also occurs in local depressions on the undulating surface of the Vashon till, and perched ground water accumulates and is available from shallow dug wells. Because such perched aquifers are limited in extent and storage capacity, the water levels normally exhibit a marked seasonal fluctuation, and many such aquifers become depleted during the late summer months.

Younger Clay

As the younger clay is usually found above the water table and is highly impermeable, it is of no importance as an aquifer in the report area. Moreover, because it mantles the surface in a few low bank shoreline areas, the clay tends to impede the downward percolation of precipitation to the underlying aquifers.

Recent Alluvium

Except where the water table intersects these materials near ground surface adjacent to streams and lakes, Recent alluvial deposits are of little importance as aquifers. However, depending upon local characteristics of permeability, alluvium influences the rate of downward percolation of precipitation to the local water table.

AREAL OCCURRENCE OF GROUND WATER

GENERAL

Plate 2 shows the location of wells on the Kitsap Peninsula and certain adjacent islands on which information on well yields and water levels has been obtained from drillers' logs and well canvasses of the area. The well locations are designated by symbols identifying them as dug or drilled, and signifying whether or not a well log is available. The numerals beside each well describe either (1) the altitude of the water level above mean sea level and the pumping capacity in gallons per minute, or (2) the land surface altitude above mean sea level of flowing wells and the flow in gallons per minute.

Appendix A tabulates information only on wells used as a basis for the development of the diagrammatic cross sections shown on Plate 1. Information on all other wells may be obtained from the State Division of Water Resources.

As noted on Plate 2 there are large areas for which well information is not available. It may be presumed that these areas are either (1) largely unpopulated, (2) served by shallow dug wells which supply only the minimum domestic needs, (3) supplied by surface springs or streams, or (4) served by large community water systems.

The development of an extensive regional water table beneath the Kitsap Peninsula is precluded by the high degree of dissection of the land. The ground-water table beneath each peninsula and island has as its base level the surrounding marine waters. Along the shorelines of the peninsula the water table is near sea level while farther inland it rises and roughly parallels the topography of the upland areas, rising beneath hills and dropping near lakes and stream valleys. Locally, perched ground-water bodies will be found at higher altitudes where the till capping has created a relatively impermeable base underlying pockets of recessional sands and gravels. Such aquifers are usually tapped by shallow dug wells and supply the minimum domestic requirements of many of the small farmsteads which occupy the uplands.

The following discussion describes the general areal distribution and availability of ground-water supplies in the various provinces of the report area. Tables 3 through 9 list those wells within the separate provinces that have been tested by drillers to be capable of producing moderate to large supplies of ground water. Besides listing the general area, well number (see Fig. 9), and name of owner or tenant, the tabulation presents the following information:

Altitude: altitude of ground surface at well, in feet above mean sea level.
Depth and Diam.: depth of well in feet, and diameter in inches.
SWL: static water level in well before pumping, measured in feet below land surface.
Dd: drawdown in feet of water level during pumping.
Yield (gpm): gallons per minute yield of pump.
Capacity (gpm): estimated potential yield in gallons per minute when 2/3 of available drawdown is utilized.

NORTHERN UPLAND

Small to moderate supplies of ground water are obtained from sand and gravel aquifers in the northern upland. As precipitation decreases toward the northern part of the Kitsap Peninsula (Plate 4), annual recharge to the aquifers also decreases.

Most of the wells in the vicinity of Foulweather Bluff, at the extreme northern end of the report area, obtain water from sand and gravel aquifers which are usually penetrated at altitudes close to sea level. A 1206-foot gas test well was drilled at 28/2E-17M and penetrated mostly sand and clay except for a gravelly zone from 740 to 772 feet. Many of the sand zones above this gravel zone were water-bearing.

Water from most of the wells in this area is high in dissolved mineral matter, and some has an unpleasant taste.

In general, the deep wells located on upland areas must first penetrate the till and underlying deposits before reaching the Salmon Springs(?) Drift sand and gravel aquifers at or near sea level. Otherwise shallow dug wells may supply small quantities from local bodies of ground water perched on the till.

In the Kingston area ground-water withdrawals are chiefly from shallow domestic wells dug into the till or underlying materials. Deeper wells indicate the area to be underlain primarily by sand and silt. Well 27/2E-25N at the Kingston Ferry dock was drilled to a depth of 298 feet in fine-grained sediments and obtained water from a 6-foot sand stratum between 266 and 272 feet. Finished with a 0.010-inch slot screen, the well tested at about 50 gallons per minute which shows the capability of an efficiently constructed well in this area.

The water table is usually shallow beneath the lowland areas in and adjacent to Kingston, but lies more than 100 feet beneath some of the adjacent uplands. Several wells per farm may be required to obtain ground water in quantities suitable for irrigation in this area.

Other than from shallow dug wells, most of the domestic supplies in the northern upland are obtained from the several streams and spring zones located in the major upland valleys.

CENTRAL UPLAND

Records of wells on much of the central upland indicate that the materials underlying the till are generally fine grained, with sand strata forming the principal aquifers. Adequate screening or perforation and efficient well construction are required for development of irrigation or other large supplies from aquifers beneath this upland.

Tertiary sedimentary rocks of the Blakeley Formation are exposed above sea level south of Tracyton, and this belt of impermeable rocks extends beneath the southern end of the central upland. For this reason large supplies of ground water cannot be found at great depth in this area.

BAINBRIDGE ISLAND

Except for Tertiary bedrock underlying the southern part of the Fort Ward peninsula, Bainbridge Island is underlain by Pleistocene sands and silts with minor amounts of gravels. In most places on the upland these deposits are overlain by a thick mantle of Vashon till. Most of the individual domestic supplies on the island are obtained from shallow dug wells tapping perched ground water above the till. Deeper drilled wells are generally finished with open-bottom or perforated casings, obtaining water from coarser sand and gravel strata of the Colvos Sand. In general, the more permeable aquifers are found at depths of less than 200 feet below sea level. Several wells have yielded moderate to large supplies at greater depths, but the available stratigraphic data indicate that considerable risk is involved in attempting such development. The water level is shallow in most wells, seldom exceeding 100 feet below land surface.

Most wells drilled in the Eagledale district at 25/2E-35 obtain water from sand strata of the Colvos Sand near sea level. These materials yield supplies sufficient for domestic requirements, although it is not known whether or not they are capable of yielding adequate water for irrigation purposes. Depths to water locally exceed 100 feet.

Table 3. WELLS ON THE NORTHERN UPLAND CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER.

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Hansville	28/2E-16J	R. Randell	10	132 x 6	3	9	40	250+
	22B	U.S.C.G.	80	109 x 6	76	----	50	----
	32G	Cliffside Development Company	100	120 x 6	92	10	50	50
Port Gamble	27/2E-7A	Pope & Talbott, Inc.	40	169 x 10	56	66	100	120
Lofall	27/1E-14P	Jensen, Richards, & Olhava, Inc.	50	126 x 16	35	42	60	80
Kingston	27/2E-25D1	Kingston Water Users Corp.	260	60 x 24	0	17	65	150
	25D2	U.S. Corps of Engineers	260	295 x 6	230	24	20	40
	25N	State of Washington (ferry dock)	5	298 x 8	----	----	50	----
Indianola	26/2E-10R1	O. C. Gray	120	70 x 8	0	35	35	50
	10R2	O. C. Gray	120	260 x 8	90	120	24	24
Suquamish	26/2E-16P	Suquamish Improvement Co.	120	150 x 8	10	15	25	200
Poulsbo	26/1E-13C	D. R. Stevenson	360	248 x 6	119	5	22	300+
	14G	P. Hatta	60	120 x 6	+	----	60	(Flowed 60)
	26/2E-18D	H. E. McMahill	365	284 x 6	115	35	125	400
	30M	J. Brennen	200	208 x 8	174	15	250	350

Wells in the Winslow area at 25/2E-26 & 27 obtain water from sand and gravel strata generally encountered at depths of less than 200 feet; many of these aquifers are capable of yielding small irrigation supplies.

Several wells on the upland in the Seabold area at 26/2E-33 have failed to obtain adequate supplies for even domestic requirements owing to the fineness of the materials encountered. However, since most of the unsuccessful wells bottomed at altitudes above sea level, the character and water-bearing properties of the materials lying below sea level are not known. Many wells located at low altitudes around the margin of the upland have obtained satisfactory supplies from sand and gravel strata within the first 100 feet below sea level; if these aquifers extend below the upland, they could be tapped by deeper wells on the upland.

Tertiary rocks of the Blakeley Formation underlie the southern end of Bainbridge Island. These relatively impermeable, well consolidated sedimentary rocks are found exposed in the south half of the Fort Ward peninsula and along the lower slopes overlooking Blakely Harbor. Wells dug or drilled in these areas obtain only meager supplies of ground water for domestic use, in most cases the water being obtained from overlying Pleistocene sands and gravels filling depressions in the bedrock surface. In the northern part of the Fort Ward peninsula, two or three wells have penetrated sufficient thickness of sand and gravel strata to provide moderate supplies of ground water.

WESTERN UPLAND

Generally, ground-water development on the western upland has been for domestic supplies, most of the wells being shallow dug wells that obtain perched ground water from the till or overlying outwash materials. The deeper drilled wells penetrate the till and obtain water from the underlying Colvos Sand or older formations. Several large-capacity wells have been drilled at the U.S. Naval Station at Bangor, and at the U.S. Navy base at Bremerton.

The Camp Union area is a small, sparsely populated district in the central part of the western upland at 24/1W-5, 6 and 7. The land surface is mantled by 30 to 40 feet of till, with most drilled wells passing through the till to obtain water from the underlying Colvos Sand within 150 feet of land surface. Although these wells now yield only domestic supplies, they are probably capable of yielding larger supplies with proper development.

Table 4. WELLS ON THE CENTRAL UPLAND CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER.

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Scandia	26/1E-27J	W. H. Wilson	40	86 x 6	0	5	30	350
Keyport	26/1E-36M	U.S. Navy	20	1036 x 12-22	+	50	1750	1750+
Silverdale-Dyes Inlet	25/1E-16J	R. R. Ross	200	206 x 8	99	7	25	250
	21B	C. R. Lundgreen	50	70 x 6	27	6	22	100
	28R	M. R. Kint	80	92 x 6	23	7	25	150
Gilbertson	25/1E-24H	F. Strand	15	274 x 8	+	20	250	1500+
Meadowdale	25/1E-25M	P. W. Crane	230	143 x 6	70	5	50	450
E. Bremerton	24/1E-1R	N. Perry Ave. Water Company	330	419 x 12	110	81	750	750+
	24/2E-7D	N. Perry Ave. Water Company	320	480 x 8	98	112	412	800

Table 5. WELLS CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER ON BAINBRIDGE ISLAND.

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Manzanita Bay	25/2E-17C	U.S. Navy	155	910 x 6	100	45	30	300
Winslow	25/2E-26H	M. Antoncich	125	168 x ?	----	----	"100 families"	
	26N	Federal Housing Authority	20	163 x 12	0	100	40	40
	26P	Commercial Ship Repair	10	761 x 8-4½	+	----	300	----
Fort Ward	24/2E-10B	Sy Devenny	180	98 x 12-8	35	----	60	60

In the Holly area on Hood Canal, data obtained from two deep wells indicate that the area is underlain mostly by fine-grained materials. Well 24/2W-17R in the Anderson Creek valley was drilled to a depth of 394 feet, and only a small supply was obtained from the fine-grained sediments that occurred at 28 feet and below. Well 24/2W-19A, 184 feet deep, also penetrated only fine sediments which were not very productive. In this area it appears that wells are drilled at considerable risk of failure. Since numerous springs issue along the upper surface of the clays which crop out along the valley slopes and the slope to Hood Canal, it would appear that such sources of surface-water supply would be the most reliable.

Little information is available on ground-water conditions in the shoreline area of Hood Canal between Holly and Musqueti Point (22/3W-18N). A few isolated homes and summer cabins are located near beach level or on bluffs overlooking this largely undeveloped part of the western upland. Water supplies here have been dependent upon local springs and small intermittent streams that drain the upland above. The unnamed gravels that form these bluffs are generally coarse and porous and, with few observable till or clay strata to impede downward percolation of precipitation falling upon the upland, it appears that these materials are essentially barren of ground water until saturation of the gravels is attained near sea level.

Table 6. WELLS CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER ON THE WESTERN UPLAND.

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Lofall	27/1E-33N1	I. Smith	120	200 x 6	142(?)	17	25	50
	33N2	M. C. Redman	120	260 x 6	132(?)	15	13	100
Bangor	25/1E-6D	U.S. Navy	320	207 x 8	127	15	35	100
	26/1E-32K	U.S. Navy	295	690 x 18-8	228	82	350	1500
	32L	U.S. Navy	295	165 x 8	129	2	30	300
	32M	U.S. Navy	300	700 x 10	----	----	550 (reported yield)	
Seabeck	25/1W-20D	R. Priddy	95	190 x 6	90	10	30	150
Scandia	26/1E-27J	W. H. Wilson	5	86 x 6	0	5	30	350
Chico	24/1E-5E	Erland Point Water Company	120	251 x 12	+	42	500	500
Kitsap Lake	24/1E-17B	Harlow & Burke	170	363 x 6	90	20	50	450
Bremerton	24/1E-23E	U.S. Navy	30	2000 x 26-12	----	50	1500	----
Union River	23/1W-3N	E. Maiden	160	94 x 6	52	10	24	75
Hood Canal, east arm	22/2W-1C	--- Dunsmore	10	42 x 6	10	12	100	100
	9K	Clifton Beach Coop. Water Assn.	10	71 x 6	27	18	1800(?)	1800+(?)
Upland, above Hood Canal	23/2W-13H	State Dept. of Institutions	400	180 x 6	141	15	125	250

From Musqueti Point to Tahuya and beyond, along the east arm of Hood Canal, extensive development of waterfront property has increased the demand for ground water. Ground water is being obtained from 30-to 40-foot wells drilled into the unnamed gravels and Vashon Drift sands and gravels. Water levels in these shoreline wells stand slightly above sea level and it must be expected that excessive withdrawal from such shallow wells may result in saline contamination.

In the Seabeck-Warrenville area on Hood Canal, ground water has been obtained mostly from small diameter drilled wells which penetrate the till and tap aquifers in the underlying Vashon advance gravels and Colvos Sand. Some wells obtain artesian flow where the till has served as a confining layer above the underlying sands and gravels. Well 25/1W-14F near Warrenville penetrated 208 feet of clay and silt and was eventually abandoned.

The Scandia area, a small farming and residential community located along Liberty Bay in the northern part of the western upland, is mantled by till up to 60 feet thick. Ground-water supplies are obtained mostly from shallow dug wells, although a few deeper drilled wells have produced domestic supplies. Wells 26/1E-27J and 34C penetrate as much as 138 feet of clay beneath till before the deeper gravel aquifers are reached.

SOUTHERN UPLAND

Present ground-water development in the southern upland is primarily for domestic purposes. The water table is within 100 feet of land surface in most places except the uplands adjacent to Puget Sound or deep valleys where the water level is lowered by spring seepage along the slopes. Along the shorelines of Puget Sound the water table lies slightly above sea level; similarly along the drainage courses the water table usually stands slightly above the level of the streams or lakes. The aquifers are chiefly in Pleistocene sands and gravels, except at Point Glover, where small yields have been obtained from Tertiary sedimentary rocks.

Several large-producing municipal supply wells have been drilled along the south shoreline of Sinclair Inlet in the Port Orchard-Annapolis area. Most of the wells penetrate sand and gravel materials underlying the Kitsap Formation clays and most tap confined aquifers in both the underlying Salmon Springs(?) Drift and pre-Salmon Springs(?) deposits, undifferentiated. Several wells here have artesian flows of over 100 gallons a minute, with well 24/1E-25E (City of Annapolis) having a flow of 750 gallons a minute recorded in 1949 and well 24/1E-25M (City of Port Orchard) reportedly having a flow of 400 gallons a minute. On the upland south

Table 7. WELLS CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER ON THE SOUTHERN UPLAND.

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Port Orchard-Annapolis	24/1E-25E1	Annapolis Water Dist.	35	1133 x 10	+3	55	1700	1700+
	25E2	Silver Springs Brewing Co.	10	314 x 6	+	----	130 Flow	----
	25G	Federal Housing Authority	120	1005 x 24	----	----	350	----
	26K	Town of Port Orchard	100	792 x 10-5	35	42	620	2000+
	33K	City of Bremerton	(several wells here, averaging about 50 feet elevation, depths of 245 to 587 feet, all flowing, with well capacities of 800 to over 2000 gpm.					
	33L	City of Bremerton	25	622 x 16	+	68	1080	2000+
	24/2E-31A	Annapolis Water Dist.	350	1006 x 22-16	223	91	325	1500+
Point Glover	24/2E-16K	U.S. Navy	25	136 x 18	5	33	400	1000
	16L	Watauga Beach Community Water Co.	60	141 x 8	47	25	205	600
Manchester-Yukon Harbor	24/2E-15P	U.S. Navy	63	353 x 8	53	57	200	600
	15N	U.S. Navy	92	305 x 12	79	52	60	200
	22M	Manchester Water District	15	116 x ?	11	15	150	1000
	27M	P. M. Jensen	40	100 x 6	+	25	48	150
	33H	L. Cheney	20	134 x ?	+	----	400 Flow	----
	33J	Manchester Water District	20	185 x 12-8-6	+	43	420	1500
Bethel	23/1E-1G	R. D. Russell	330	34 x 36	22	½	5	200
	14A	C. Sowa	280	145 x 6	93	7	22	100
	21J	H. L. Lamberton	390	101 x 6	6	0	40	100
	17Q	Presbytery of Seattle	440	83 x 6	57	5	20	100
Sunnyslope	23/1E-7D	Sunnyslope Water Dist.	220	220 x 8	142	28	110	200
	23/2E-7G	C. M. Dillon	160	132 x 8	91	"0"	22	100+
	23/1W-11J	Kitsap County Airport	430	150 x 48	115	½	75	200
Olalla Creek Valley	23/2E-33F	C. B. Jones	390	70 x 6	6	12	27	100
Burley Creek Valley	22/1E-1P	C. D. Carter	130	638 x 8-6-4	8	40	50	400
	4K	P. Sando	280	99 x 6	3	20	32	100
	14B	--- Bray	65	122 x 6	28	5	24	300
	12N	E. Black	20	220 x 6	+	----	600 Flow	----
	15M	D. J. Ballew	245	194 x 8	124	56	200	200
	23E	O. M. Miller	250	169 x 6	10	5	7	120
	23K	J. Jensen	10	49 x 6	26	3	24	100
	24C1	Peninsula School Dist. 401	80	153 x 6	33	45	60	150
	24C2	H. Pederson	35	105 x 6	+	----	60 Flow	----
	24F	Heaton-Pederson-Johnson	40	151 x 6	+	30	40	150
	22/2E-17M	---Hedstrom	345	124 x 6	107	1	20	250

Table 7. WELLS CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER ON THE SOUTHERN UPLAND. (continued)

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Gig Harbor-Crescent Creek valley	21/2E-5K	Harbor Springs Water Company	70	156 x 10	46	24	40	120
	22/2E-32G	L. Sivertsen	85	175 x 6	+	----	100 Flow	
	32P	Town of Gig Harbor	30	120 x 10	+	75	400	(Flows 30 gpm)

of Port Orchard some difficulty has been experienced in developing large ground-water supplies, owing undoubtedly to the wells not being drilled deep enough to go beneath the sands and silts of Colvos Sand and Kitsap Formation which in this area are not saturated much above sea level. It is probable that wells drilled 100 to 200 feet below sea level would tap the more productive deeper sands and gravels of the Salmon Springs(?) Drift and older deposits.

Blackjack Creek valley, a few miles south of Port Orchard, is one of the more important farming districts of the southern upland. This upland valley is surrounded by till-mantled uplands which rise to 200 feet above the valley floor. The valley floor and lower parts of the surrounding slopes are underlain by Colvos Sand and probably some Vashon recessional outwash sands. To date only one or two wells have been drilled in the Blackjack Creek valley for the purpose of irrigation, most wells being used for domestic supply or small community systems. Most irrigation water in the valley is obtained from Blackjack Creek and adjacent tributaries. However, with proper well construction and penetration into the deeper aquifers in the Colvos Sand and Salmon Springs(?) Drift, wells in this area should produce 50 to 100 gallons a minute. As the water table here lies slightly above creek level, shallow dug or drilled wells tapping the finer valley sediments adjacent to the streams produce sufficient quantities of water for domestic purposes. Depth to water beneath the slopes rising from the valley floor generally increases with distance from the streams.

A low divide separates the drainages of northward-flowing Blackjack Creek and southward-flowing Burley Creek, although both drainages together form a shallow north-south trending trough. The Burley Creek valley, like the Blackjack Creek valley, is underlain by the Colvos Sand and Vashon recessional outwash. Here, too, ground-water development for irrigation purposes has been small, with most irrigation water being supplied from Burley Creek and tributaries. In the upper Burley Creek valley it is probable that moderate to large supplies of ground water can be obtained from wells drilled to depths of 200 to 400 feet and tapping the deeper aquifers of the Colvos Sand and underlying Salmon Springs(?) Drift.

In the lower part of Burley Creek valley, near Burley and Purdy, several wells, penetrating confined aquifers in the Salmon Springs(?) Drift and pre-Salmon Springs(?) deposits 200 to 375 feet below sea level, have produced large artesian flows. Artesian flow has been obtained from such wells located less than 120 feet above sea level along the valley slopes, with artesian pressure increasing in those wells drilled at lower altitudes. Water obtained from these deeper aquifers has an odor of hydrogen sulfide. On the uplands bordering the Burley Creek valley small domestic supplies are obtained from shallow dug wells penetrating water bodies perched on the till.

Another major shallow trough lies in the eastern part of the southern upland and is herein called the Curley Creek-Long Lake-Olalla Creek valley. Beginning near Colby on Yukon Harbor at 24/2E-33R, the valley ascends at a low gradient southwesterly up the Curley Creek drainage to Long Lake, beyond which a low drainage divide is crossed and the Olalla Creek valley descends in an equally low gradient southeasterly to Olalla Bay on Colvos Passage at 22/2E-3M. The entire length of the valley is underlain by Colvos Sand and Vashon recessional deposits, and the water table is shallow along the valley floor, being slightly above stream and lake level in most places. Most of the domestic requirements of the small farmsteads occupying the stream valleys and the waterfront homes on Long Lake are supplied by shallow dug and drilled wells and by the numerous springs which issue along the slopes adjacent to the valley floor. Irrigation of small farms is done almost entirely from the creeks occupying the valleys. It is probable that moderate to large supplies of ground water may be developed through wells drilled into the deeper aquifers of the underlying Salmon Springs(?) Drift. On the uplands adjacent to the valley, domestic supplies are obtained from shallow dug wells tapping small local aquifers perched on the till.

Point Glover is a rural residential area five miles northeast of Port Orchard. As most of the area is underlain by Tertiary sedimentary rocks of the Blakeley Formation, there has been little ground-water development there. Springs issuing along the surface of the bedrock and draining small pockets of sand and gravel supply some domestic requirements. A few wells supply two to three gallons per minute, but the large community supply systems must pipe water from wells drilled into thicker unconsolidated Pleistocene materials a mile and a half south of the Point. A 136-foot deep U.S. Navy well (24/2E-16K) yields about 400 gallons a minute, and well 24/2E-16L, belonging to Watauga Beach Community Water Company, 141 feet deep, has a capacity of 600 gallons a minute from these materials.

Blake Island located in Puget Sound one and a half miles north of Point Southworth has in recent years been the subject of much speculation as to the possibility of obtaining an adequate supply of ground water for the requirements of Blake Island State Park. Several test holes were drilled before well 24/2E-25P was drilled at an altitude of 160 feet near the highest point on the island. The well was drilled to a depth of 190 feet and yielded about 50 gallons a minute. The water level stood at about 15 feet above sea level.

Table 8. WELLS CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER ON VASHON AND MAURY ISLANDS.

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Vashon Island	21/2E-1M	D. A. McIntyre	300	183 x 6	138	4	20	150
	22/2E-24K	H. Boyd	300	193 x 8	129	10	50	200
Maury Island	22/3E-16F	Queen City (KIRO) Broadcasting Co.	60	462 x 8	55	60	40	300
	21J	A. A. Schmidt	400	518 x 6	378	?	25	25+
	22K	Boise-Cascade Corp.	210	348 x 12	203	26	300	300+
	23D	Wise Investment Co.	400	382 x 8	338	17	30	300
	31J	---Fischer	360	493 x ?	----	----	40	40+
	32C	Bard & Howard	240	423 x 12	238	80	128	200

Table 9. WELLS CAPABLE OF PRODUCING MODERATE TO LARGE SUPPLIES OF GROUND WATER ON THE GIG HARBOR PENINSULA AND FOX ISLAND.

General area	Well Number	Owner/Tenant	Altitude	Depth and Diam.	SWL	Dd	Yield (gpm)	Capacity (gpm)
Upland north of Narrows Bridge	21/2E-8C	Town of Gig Harbor	60	375 x 18	----	31	340	340+
	17K	W. Hogan	320	397 x 8	220	5	100	500+
	21C	Westbridge Water Co.	200	255 x 8	195	7	35	150
Wollochet Bay	21/2E-24J	S. Crooks	10	35 x 6	+	19	60	70
	30D	D. C. Rowland	40	66 x 6	28	6	20	80
	30F	P. R. Faber	40	65 x 6	35	25	66	50
	30D	Wollochet Harbor Club & D. Rowland	130	193 x 8	125	10	80	400
Fox Island	20/2E-6N	F. H. Nichols	75	119 x 8	70	13	45	100
	2Q	A. F. Caldwell	200	122 x 6	62	15	40	80

Other parts of the southern upland are not heavily populated and little information is available on the ground-water potential except along the shoreline areas of Case Inlet, Henderson Inlet and Colvos Passage. There beach homes obtain water from spring zones located along the upper surface of the Kitsap Formation near beach level, and from wells drilled to depths that tap ground water near sea level. Most are 6-inch wells that were bail-tested at 20 to 100 gallons a minute, and obtain water from the Colvos Sand and Salmon Springs(?) Drift gravels. The western half of the southern upland is largely mantled by thick deposits of coarse gravels of Vashon ablation till and recessional outwash; these deposits have discouraged development of the area for farmsteads and little information is therefore available on the ground-water potential there. The few small farms located along stream valleys and summer homes located on the shores of small lakes scattered across this part of the southern upland obtain water supplies from these surface-water bodies or from shallow wells dug adjacent to the streams and lakes.

VASHON-MAURY ISLANDS

As in other upland areas of the Kitsap Peninsula, Vashon and Maury Islands are underlain by varying thicknesses of Vashon Drift. The development of ground-water supplies on these islands has been limited chiefly to shallow dug domestic wells that supply the farmsteads not otherwise served by community water systems. A few deeper drilled wells obtain water for irrigation of some upland farms and for small group domestic supplies. Drillers' records and data on pump tests and well yields are lacking for much of the area. In a few places on the uplands domestic supplies are obtained from large cisterns constructed to capture rainfall from roof drain-pipes.

Although springs have provided the primary sources of community water supplies for Vashon and Maury Islands, future development and residential growth of the islands will depend more heavily upon ground-water supplies developed from deeply drilled wells. Moderate supplies of ground water are probably available to wells that tap deeper aquifers in the Colvos Sand and in the Salmon Springs(?) Drift. Near sea level along shoreline areas water can be obtained locally from relatively shallow wells. On the upland areas the water table stands at altitudes of 100 to 200 feet above sea level.

GIG HARBOR PENINSULA-FOX ISLAND

The upland areas of the Gig Harbor peninsula and Fox Island are mantled in most places by Vashon till and recessional outwash which supply perched ground water to shallow dug domestic wells. The till also serves to underlie spring zones on the uplands. Springs also occur at the upper surface of the Kitsap Formation exposed along shoreline bluffs, and provide local domestic supplies although no large quantities of surface water have been developed on the peninsula for community supplies.

Drilled wells obtain water at or slightly above sea level along the shorelines of the peninsula and Fox Island. Farther inland the water table rises and deeper wells drilled on the uplands tap aquifers in the Colvos Sand and Vashon advance outwash at elevations of 50 to 150 feet above sea level in most places.

LONGBRANCH PENINSULA

The Longbranch peninsula is mantled in most places by Vashon till, with pockets of recessional sands and gravels overlying the till in local depressions. Several small lakes and marshy areas are perched on the underlying till. Some upland areas, along the highway south of Key Center and the adjacent slopes leading eastward to Carr Inlet (21/1E-7) are underlain by a thick sequence of recessional sand and Colvos Sand. The broad stream valley heading Whitman Cove at 20/1W-16 and extending northward toward Home is also composed predominately of a thick sequence of brown sand that is either Vashon recessional outwash or Colvos Sand.

Most of the water for irrigation supplies developed on the peninsula comes from small ponds and lakes scattered over the upland and from the few small streams that drain the upland. A few marshy areas have been developed for irrigation and stock supply ponds by earth dams. Along the shoreline of the peninsula local springs issuing from the upper surface of the Kitsap Formation provide domestic supplies for beach homes.

Ground-water development on the Longbranch peninsula has been limited mostly to shallow dug or drilled domestic wells; only a few deep wells have been drilled to obtain water from saturated sands and gravels in the Vashon advance outwash and Colvos Sand. The water table is close to sea level along the shoreline but further inland it occurs at elevations considerably higher than sea level. Due to the lack of deep drilling in most of the upland area, there is only limited information on the availability of ground water. However, with the anticipated future growth of the area will come an increasing demand for development of ground-water supplies.

Herron Island has been developed as a residential community. The domestic water supply is obtained from a well drilled nearest the highest point of the island, at the 120-130 foot altitude. The well is 200 feet deep and has a static water level which has been measured at, and slightly below, sea level. This situation would suggest the possibility of saltwater contamination, although under present use and pumping conditions the water is reported to be of good quality.

ANDERSON ISLAND

The small present demand for domestic water supplies for beach homes on Anderson Island has been satisifed by small springs that issue at the upper surface of the Kitsap Formation along the shoreline slopes of the island and by shallow dug or drilled wells that obtain ground water near sea level. A few upland homes obtain domestic supplies from shallow ground water perched on the till.

The future development of the waterfront properties of Anderson Island will undoubtedly increase the demand for ground water as a source of water supply. To date little exploration has been made of the ground-water potential of the island; however, geologic evidence suggests that wells drilled on the upland should penetrate saturated portions of the Colvos Sand and gravels at elevations of 25 to 75 feet above sea level. Deeper wells drilled through both the Colvos sand and underlying Kitsap Formation should obtain moderate to large supplies of ground water from gravels within the Salmon Springs(?) Drift or pre-Salmon Springs(?) deposits. It is recommended that exploratory drilling be conducted in the central upland portions of the island to determine the water-bearing characteristics of the formations underlying the Vashon Drift.

RECORDS OF WELLS

During the course of the investigation of Kitsap County proper by Sceva (1957) more than 1,200 wells were scheduled and data for 1,146 were tabulated. Of the wells tabulated 565 were dug, 570 were drilled, 5 were jetted, 2 were bored and 1 was driven; three deep oil test wells were also listed.

Information on wells located in the Mason, Pierce, and King County parts of the present study area was obtained from both well drillers and from drillers' records filed with the Division of Water Resources in conjunction with processing of ground-water rights. In some areas barren of such information a spot-check well canvass was conducted. Many areas, as shown on Plate 2, are relatively barren of data on water levels and well capacities due in large part to the lack of development of ground water as a source of supply. Since shallow dug wells greatly outnumber drilled, bored, and driven wells in the study area, it is presumed that shallow ground water is available for domestic supplies in most places.

Owing to space limitations a detailed tabulation of well logs and pump capacities of all recorded wells has not been included in this report, although for each well spotted on Plate 2 a record is maintained in the files of the Division of Water Resources. These records are available upon request, with detailed drillers' logs being available for those wells shown by solid square or circular dot.

For those wells shown in the diagrammatic geologic cross sections on Plate 1, a detailed tabulation of well logs is presented in Appendix A.

GROUND-WATER DEVELOPMENT

DEEP WELLS

Except in a few notable cases, wells that penetrate the deeper deposits underlying the Kitsap Peninsula have been generally unsuccessful in producing large supplies of ground water. This is due primarily to the fineness and general impermeability of the materials encountered at depths generally greater than 150 feet below sea level, where the pre-Salmon Springs(?) deposits, undifferentiated, are found. In several of the more productive deep wells the location of the chief aquifers is not known because the casings are usually perforated at numerous horizons.

Within Kitsap County proper, Sceva (1957) has tabulated 28 wells drilled to depths of 500 feet or more. Of these, 10 have been abandoned owing to insufficient yield or excessive drawdown. In three of the abandoned wells Tertiary sedimentary rocks are known to have been penetrated. Eighteen of the deep wells are in use. Of these, eight are capable of yielding large supplies, seven yield small to moderate supplies, and the yield of the remaining three is unknown. The foregoing data would infer that considerable risk is involved in the construction of deep wells except in areas of known production.

SHALLOW DRILLED WELLS

Drilled wells that have most successfully produced ground water in the report area are those that have tapped the sand and gravel aquifers occurring within the saturated lower portions of the Colvos Sand. The aquifers usually occur below the regional water table which lies above sea level along the shorelines and rises inland to 100 to 150 feet or more above sea level. Deeper gravel aquifers within the Salmon Springs(?) Drift also produce moderate to large supplies of ground water, normally from depths at or slightly below sea level. However, although the Salmon Springs(?) Drift is usually found below the water table and the sands and gravels are therefore normally saturated, the presence of this formation below the overlying Kitsap Formation is not usually known until drilling tests have proven its existence in a given location. For that reason test drilling is recommended.

DUG WELLS

In many of the settled upland areas within the report area minimum domestic supplies are obtained from perched ground water tapped by shallow dug wells. In most cases the construction of such wells have not required the services of well drillers, and little information on those wells has been reported through drillers' records. However, a field canvass of the report area has shown that a large part of the upland's domestic requirements has been supplied from dug wells. Such wells, owing to penetration of the till mantle ("hardpan"), may not require casing, but where lined they are usually cased with three-foot diameter tile. The shallow dug wells are normally 15 to 30 feet deep.

SPRINGS

Many springs and seeps issuing from the top of impermeable silts and clays of the Kitsap Formation and Colvos Sand exist throughout the report area. The silts and clays serve as a perching layer to the downward percolation of much of the precipitation that falls upon the area. The springs provide an important part of the base flow of surface streams, and have satisfied the domestic requirements for both individual homes and communities throughout the area.

WATER LEVELS

In most places in the report area, the depth to water in wells is within 100 feet of the land surface. Wells having a greater depth to water are generally located near deep gullies or steep slopes leading to Puget Sound where natural ground-water discharge drains the shallower materials. Many of the wells that have depths to water of less than 50 feet are located at low altitudes or adjacent to streams and lakes in upland valleys. Dug wells are usually less than 25 feet deep and are located either adjacent to streams or lakes, or on uplands where they tap small bodies of perched ground water. These latter wells usually experience considerable seasonal fluctuation of water level, such perched ground water being normally characterized by rapid response to precipitation.

Plate 2 shows the location of wells throughout the study area and includes figures (in blue) that give the altitude above sea level of the water surface. Depth to water level from land surface can be calculated by subtracting these figures from the land surface elevation as interpolated from the topographic contour lines shown on U.S. Geological Survey quadrangles.

The water table is not a static surface but fluctuates due both to seasonal changes in amounts of precipitation that recharge the ground-water body and to the amount of ground-water discharge, either by pumping or by variations in the discharge of springs throughout the year. Some wells were measured periodically over several years to determine the trend and approximate annual range in fluctuation. Hydrographs of three of these wells are shown in Figure 24. These wells were selected partly because they show a comparison between the seasonal fluctuations in relatively shallow water-bearing zones and in deeper aquifers. It can be noted that while the two shallow wells have fluctuations of up to 15 feet, the deeper well has a fluctuation of only 4 to 6 feet. The difference is due primarily to the more shallow aquifers responding more quickly to the fluctuating pattern of precipitation throughout the year and frequently represent only perched, local ground-water conditions, whereas the water levels of deeper aquifers reflect the more stable cumulative effect of annual precipitation and represent the regional water table. It is also noted that, with increasing depth and with all other conditions being equal (such as permeability of materials), a greater time-lag is experienced in the response of the water table to recharge by annual precipitation. Shallow wells will normally attain their highest water levels within a month following the peak of precipitation, whereas the deeper wells may not experience their highest water levels until 3 to 4 months after the maximum precipitation.

The period of lowest water levels occurs in the late autumn or early winter months. Many owners of dug wells have found it convenient to deepen their wells during this period. High water levels occur in late winter, spring, or early summer months, depending upon the depth to the water table and upon the permeability of the overlying materials.

Because the period of low water levels in many wells corresponds in time with the first frost and accumulation of snow packs in the Cascade and Olympic Mountains, and high water levels often correspond in time to periods of greatest snowmelt and runoff in the mountains, a popular misconception has evolved claiming that ground water in the Kitsap Peninsula is derived from snowmelt in the Cascade and Olympic Mountains. However, the great depth of the surrounding waterways of Puget

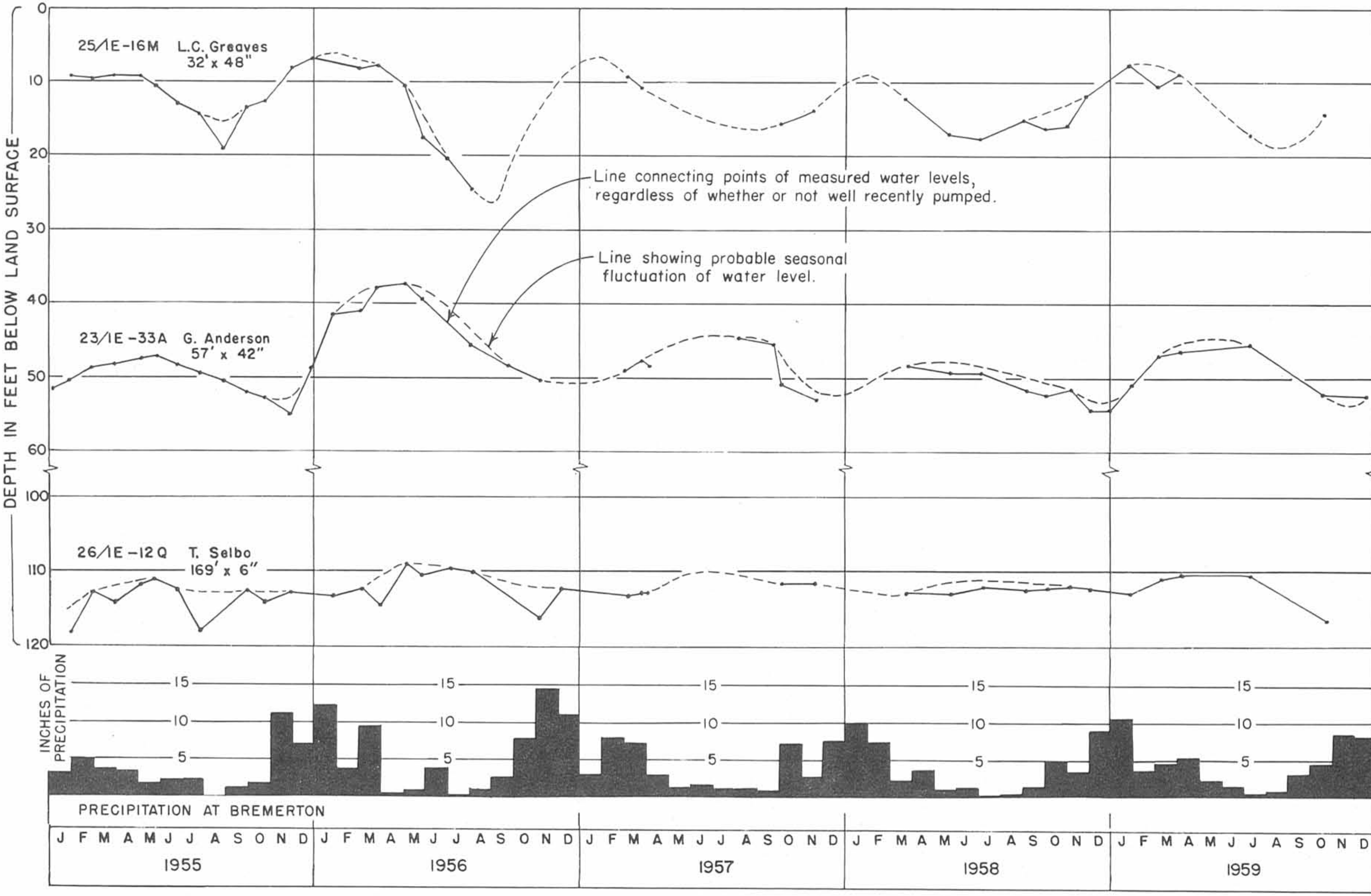


Figure 24. PRECIPITATION AT BREMERTON AND HYDROGRAPHS OF THREE WELLS IN THE KITSAP PENINSULA. Shows time relationship between precipitation and water levels in wells of varying depths.

Sound and the general movement of ground water toward these waterways within the report area preclude any recharge from these sources. All recharge comes from precipitation falling directly on the project area and percolating to the water table.

Studies made by Sceva (1957) of a water-table well, a perched lake lying in a closed depression, and a stream were compared with the monthly distribution of precipitation. It was shown that Panther Lake (24/1W-31) and Blackjack Creek near Port Orchard reflect an almost immediate response to late summer precipitation. The well, however, did not respond until several months after the rains had commenced. The level of Panther Lake would probably correspond to fluctuations of shallow perched ground water.

PERENNIAL YIELD

The perennial yield of an aquifer is defined as the rate at which ground water can be withdrawn without depleting the aquifer beyond the point of its being annually recharged. Withdrawals in excess of that rate will cause a lowering of the water table and, consequently, a reduction of the base flow of surface streams and, in places, encroachment of water of inferior quality.

Plate 4 shows that the average annual precipitation on the Kitsap Peninsula ranges from less than 26 inches in the northern part to more than 80 inches in the central part. Only a part of the precipitation reaches the water table, and only a part of this becomes available for ground-water withdrawal. Sceva (1957) estimates that in areas having 25 to 30 inches of precipitation the perennial yield might be as much as 1 acre-foot per acre per year, and in areas having 50 to 70 inches of precipitation the perennial yield will be as much as 2 to 3 acre-feet per acre per year. However, the local geologic setting, especially in the presence of thick capping layers of relatively impervious till, will reduce those estimates for many places.

At present, only a small part of the available ground water is being withdrawn. However, the rapidly increasing development of the Kitsap Peninsula and adjacent islands will undoubtedly be paralleled by an increase in ground-water withdrawal through both individual domestic wells and community supply wells. Accordingly, in some areas pumping may eventually exceed perennial yield and will result in a gradual lowering of the water table and, in some shoreline areas, possible encroachment of saline waters.

ARTIFICIAL RECHARGE

As naturally-occurring ground waters have adequately supplied the domestic and community wells in the report area, there has been to date no demand for a study of the possibilities for artificial recharge of the Peninsula's aquifers.

In addition to a demand for additional ground-water storage, an effective program of ground water-recharge must require two principle conditions: (1) an aquifer which is capable of receiving additional water at a rate that exceeds natural ground-water discharge, and (2) an available source of good-quality water to be introduced into the aquifer.

In the Kitsap Peninsula it is believed that some aquifers would be capable of receiving additional water by artificial recharge, especially during the summer months. However, large supplies of surplus water would be needed to make such a program practical and the accomplishment of a large-scale artificial recharge program, therefore, might not be possible without costly import of large quantities of water from outside the report area. Furthermore, as the strata of unconsolidated, water-bearing sands and gravels are essentially horizontal throughout the report area, and above sea level are generally truncated at sea cliffs and valley sides, there is normally a natural loss of some of the ground water by lateral seepage, both to surface springs and streams and to surrounding marine waters. Under such conditions, additional water introduced into certain aquifers would probably not be retained to any extent.